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Science 8: Human Biology

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Chapter 1

MS What is a Living Organism?

How do we tell the difference between a living thing and a non-living thing? Think about your own body. How do you know that you are alive? Your heart beats. You breathe in air. Do all living things need to do be like you in order to be ”alive”?

The above image represents bacteria. Do these bacteria look like they could be alive? They do not have hands or feet or a heart or a brain, but they are actually more similar to you than you may think. Scientists found that all living things share certain characteristics. In this chapter, we will discover how to precisely define living things.

1.1 Characteristics of Living Organisms

Lesson Objectives

- List the defining characteristics of living things.
- List the needs of all living things.

Vocabulary

cell embryo homeostasis
organism

Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or **organisms**. It might seem hard to think of similarities among such different organisms, but they actually have many things in common. Living things are similar to each other because all living things evolved from the same common ancestor that lived billions of years ago. See `http://vimeo.com/16794275` for a powerful introduction to life.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.
3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment (**homeostasis**).

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. The work you do each day, from walking to writing and thinking, is fueled by energy. But you are not the only one. In order to grow and reproduce, all living things need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat. Here is how animals, plants and fungi obtain their energy:

- All animals must eat plants or other animals in order to obtain energy and building materials.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of photosynthesis.
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (**Figure** 1.1).

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

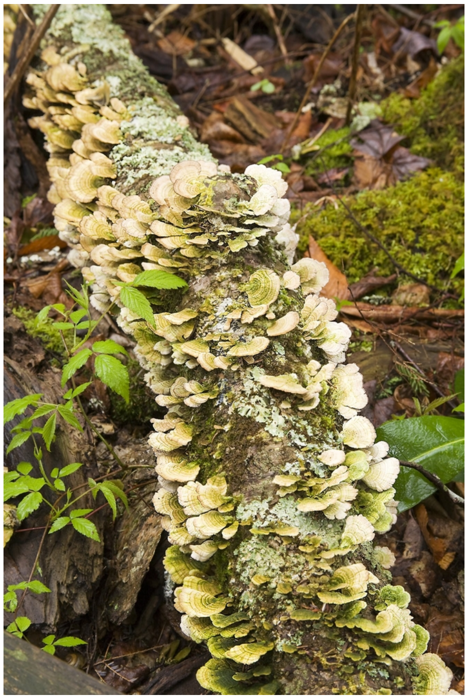


Figure 1.1: Bracket fungi and lichens on a rotting log in Cranberry Glades Park near Marlinton, West VIrginia. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Living Things Are Made of Cells

If you zoom in very close on the skin on your hand, you will find cells (**Figure** 1.3). **Cells** are the smallest unit of living things. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the paramecium shown in **Figure** 1.4 are made of just one cell. Other organisms have millions of cells. On the other hand, eggs are some of the biggest cells around. A chicken egg is just one huge cell.

The Inner Life of the Cell can be viewed at `http://www.youtube.com/watch?v=Mszlckmc4Hw` (5:28).

Figure 1.2: The Inner Life of the Cell (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/588

All cells share at least some structures. Although the cells of different organisms are built differently, they all function much the same way. Every cell must get energy from food, be able to grow and reproduce, and respond to its environment.

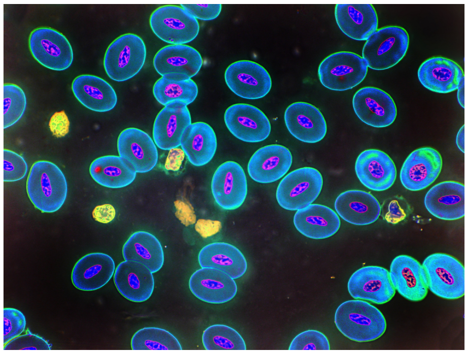


Figure 1.3: Reptilian blood cell showing the characteristic nucleus. A few smaller white blood cells are visible. This image has been magnified 1000 times its real size.

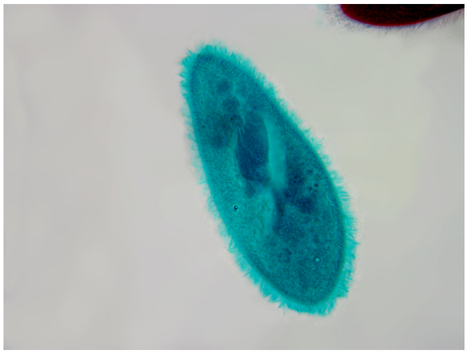


Figure 1.4: This paramecium is a single-celled organism.

Living Things Respond to their Environment

All living things are able to react to something important or interesting in their external environment. For example, living things respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, and taste buds.

Living Things Grow and Reproduce

All living things reproduce to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce (**Figure** 1.5).

Figure 1.5: Like all living things, cats reproduce themselves and make a new generation of cats. When animals and plants reproduce they make tiny undeveloped versions of themselves called , which grow up and develop into adults. A kitten is a partly developed cat.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living thing gets thrown off balance, its body or cells help them return to normal. In other words, living things have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis**. Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm (**Figure** 1.6).

Lesson Summary

- All living things grow, reproduce, and maintain a stable internal environment.
- All organisms are made of cells.
- All living things need energy and resources to survive.

Review Questions

Recall

1. Define the word organism.
2. What are three characteristics of living things?

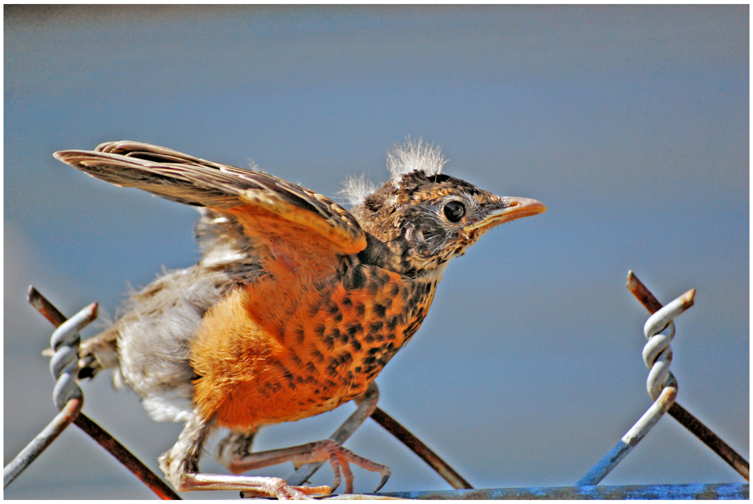


Figure 1.6: A bird fluffs his feathers to stay warm (keep from losing energy) and to maintain homeostasis.

Apply Concepts

3. What are a few ways organisms can get the energy they require?
4. What is a cell?

Think Critically

5. Think about fire. Can fire be considered a living thing? Why or why not?

Points to Consider

- DNA is considered the "instructions" for the cell. What do you think this means?
- What kinds of chemicals do you think are necessary for life?
- Do you expect that the same chemicals can be in non-living and living things?

1.2 Chemicals of Life

Figure 1.7: Life on a rocky peak in the Waitakere Ranges.

Lesson Objectives

- Define matter, element, and atom.
- Name the four main classes of organic molecules that are building blocks of life.

Vocabulary

atom atomic number carbohydrate
chemical reaction compound electron
element enzyme lipid
macromolecule matter molecule
neutron nucleic acid organic compound
Periodic Table product protein
proton reactant

Check Your Understanding

- What are the main properties of all living things?
- What is homeostasis?

The Elements

If you pull a flower petal from a plant and break it in half, and take that piece and break it in half again, and take the next piece, and break it half and so on and so on, until you cannot even see the flower anymore — what do you think you will find? Scientists have broken down **matter**, or anything that takes up space and has mass, into the smallest pieces that cannot be broken down anymore. Rocks, animals, flowers, and your body are all made up of matter (see 1.7.

Matter is made up mixture of things called elements. **Elements** are substances that cannot be broken down into simpler substances. There are more than 100 known elements, and 92 occur naturally around us. The others have been made only in the laboratory.

Inside of elements, you will find identical atoms. An **atom** is the simplest and smallest particle of matter that still has chemical properties of the element. Atoms are the building block of all of the elements that make up the matter in your body or any other living or non-living thing. Atoms are so small that only the most powerful microscopes can see them.

Each element has a different type of atom, and is represented with a one or two letter symbol. For example, the symbol for oxygen is O and the symbol for helium is He.

Atoms themselves are composed of even smaller particles, including positively charged **protons**, uncharged **neutrons**, and negatively charged **electrons**. Protons and neutrons are located in the center of the atom, or the nucleus, and the electrons move around the nucleus. How many protons an atom has determines what element it is. For example, Helium (He) always has two protons (**Figure** 1.8), while Sodium (Na) always has 11. All the atoms of a particular element have the exact same number of protons, and the number of protons is that element's **atomic number**.

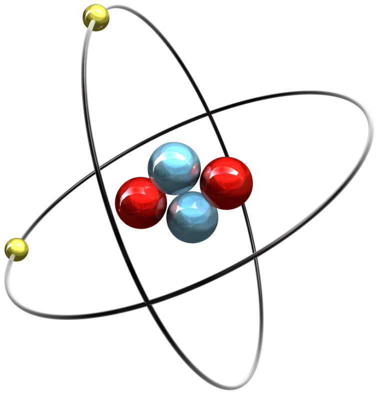


Figure 1.8: An atom of Helium (He) contains two positively charged protons (red), two uncharged neutrons (blue), and two negatively charged electrons (yellow).

The Element Song can be heard at `http://www.youtube.com/watch?v=DYW50F42ss8` (1:25)

The Periodic Table

In 1869, a Russian scientist named Dmitri Mendeleev created the **Periodic Table**, which is a way of organizing elements according to their unique characteristics, like atomic number, density, boiling point, and other values (see **Figure** 1.10). Each element has a one or two letter symbol. For example, H stands

Figure 1.9: Tom Lehrer CHEMISTRY element song (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/466

for hydrogen and Au for gold. The vertical columns in the periodic table are known as groups, and elements in groups tend to have very similar properties. The table is also divided into rows, known as periods.

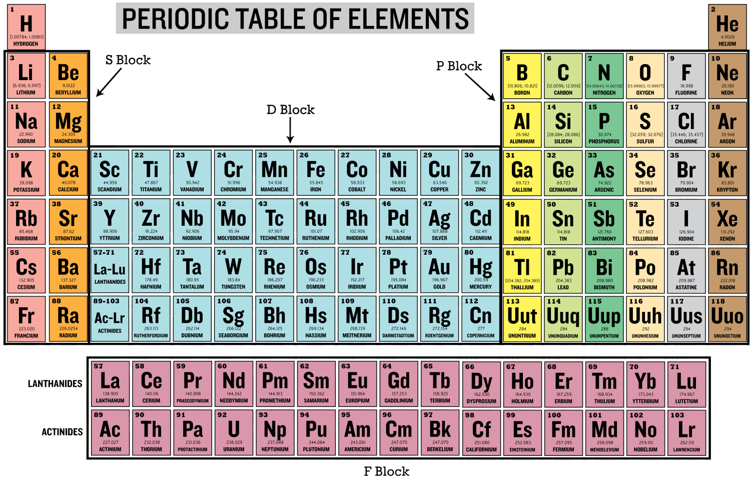

PERIODIC TABLE OF ELEMENTS
S Block
P Block
D Block
F Block
LANTHANIDES
ACTINIDES
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La-Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac-Lr Rf Db Sg Bh Hs Mt Ds Rg Cn Uut Uuq Uup Uuh Uus Uuo
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

Figure 1.10: The periodic table groups the elements based on their properties.

Chemical Reactions

A **molecule** is any combination of two or more atoms. The oxygen in the air we breathe is two oxygen atoms connected by a chemical bond to form O_2, or molecular oxygen. A carbon dioxide molecule is a combination of one carbon atom and two oxygen atoms. Because carbon dioxide includes two different elements it is a compound as well as a molecule.

A **compound** is any combination of two or more elements. A compound has different properties from the elements that it contains. Elements and combinations of elements make up all the many types of matter in the universe. A **chemical reaction** is a process that breaks or forms the bonds between atoms.

For example, hydrogen and oxygen bind together to form water. The molecules that come together to start a chemical reaction are the **reactants**. So hydrogen and oxygen are reactants. The **product** is the end result of a reaction. In this example, water is the product.

Organic Compounds

The chemical components of living organisms are known as **organic compounds**. Organic compounds are molecules built around the element carbon (C). Living things are made up of very large molecules. These large molecules are called **macromolecules** because "macro" means large. Our body gets the organic molecules we need from the food we eat (**Figure** 1.11). Which organic molecules do you recognize from the list below?

The four main macromolecules found in living things, shown in **Table** 1.1, are:

1. Proteins
2. Carbohydrates
3. Lipids
4. Nucleic Acids

What are proteins and what do they do? can be seen at `http://ghr.nlm.nih.gov/handbook/howgeneswork/protein`. *What is DNA?* can be viewed at `http://ghr.nlm.nih.gov/handbook/basics/dna`.

Figure 1.11: A healthy diet includes protein, fat, and carbohydrate, providing us with organic molecules.

Table 1.1:

	Proteins	**Lipids**	**Carbohydrates**	**Nucleic Acids**
Elements	C,H,O,N,S	C,H,O	C,H,O,P	C,H,O,P,N
Examples	Enzymes, muscle fibers, antibodies	Sugar, Starch, Glycogen, Cellulose	Phospholipids in membranes, fats, oils, waxes, steroids	DNA, RNA, ATP
Monomer (small building block molecule)	Amino acids	Often include fatty acids	Often include fatty acids	Nucleotides

The *Molecules of Cells,* an overview of the molecules of the cell, can be viewed at `http://www.youtube.com/watch?v=Q1dRmbCC04Y&#38;feature=fvw` (6:09).

Figure 1.12: Organic Cpds (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/589

Carbohydrates

Carbohydrates are sugars or long chains of sugars. An important role of carbohydrates is to store energy. Glucose (**Figure** 1.13 is a simple sugar molecule with the chemical formula $C_6H_{12}O_6$.

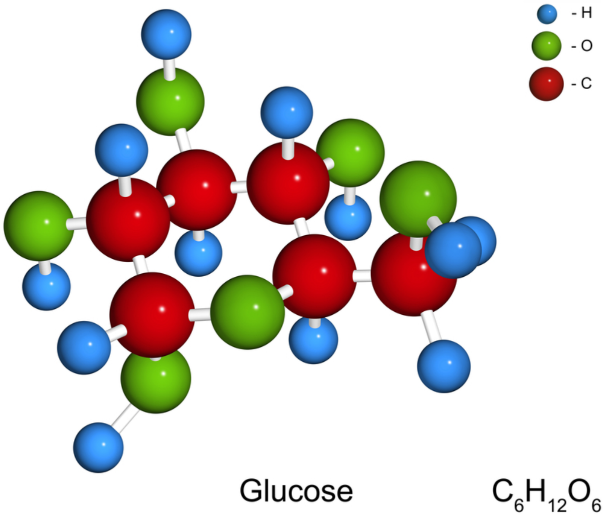


Figure 1.13: A molecule of glucose (a carbohydrate).

Carbohydrates also include long chains of connected sugar molecules. Plants store sugar in long chains called starch, whereas animals store sugar in long chains called glycogen. You get the carbohydrates you need for energy from eating carbohydrate-rich foods, including fruits and vegetables, as well as grains, such as bread, rice, or corn.

Proteins

Proteins are molecules that have many different functions in living things. All proteins are made of small molecules called amino acids that connect together like beads on a necklace (**Figure** 1.14) and **Figure** 1.16). There are only 20 common amino acids needed to build proteins. These amino acids form in thousands of different combinations, making 100,000 or more unique proteins in humans. Proteins can differ in both the number and order of amino acids. Small proteins have just a few hundred amino acids. The largest proteins have more than 25,000 amino acids.

Many important molecules in your body are proteins. **Enzymes** are a type of protein that speed up chemical reactions. For example, your stomach would not be able to break down food if it did not have

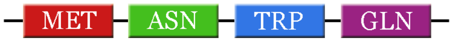


Figure 1.14: Amino Acids connect together like beads on a necklace.

special enzymes to speed up the rate of digestion. Antibodies that protect you against disease are proteins. Muscle fiber is mostly protein (**Figure** 1.15).

Figure 1.15: Muscle fibers are made mostly of protein.

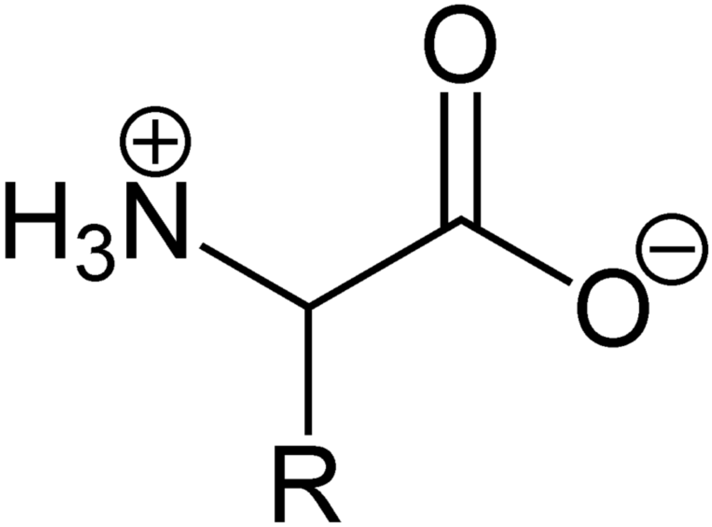


Figure 1.16: General Structure of Amino Acids. This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

It's important for you and other animals to eat food with protein because we cannot make some amino acids ourselves. You can get proteins from plant sources, such as beans, and from animal sources, like milk or meat. When you eat food with protein, your body breaks the proteins down into individual amino acids and uses them to build new proteins. You really are what you eat!

Lipids

Have you ever tried to put oil in water? They don't mix. Oil is a type of lipid. **Lipids** are molecules such as fats, oils, and waxes. The most common lipids in your diet are probably fats and oils. Fats are solid at room temperature, whereas oils are fluid. Animals use fats for long-term energy storage and to keep warm. Plants use oils for long-term energy storage. When preparing food, we often use animal fats, such as butter, or plant oils, such as olive oil or canola oil.

There are many more type of lipids that are important to life. One of the most important are the phospholipids (see the chapter titled *Cell Functions*) that make up the protective outer membrane of all cells (**Figure** 1.17).

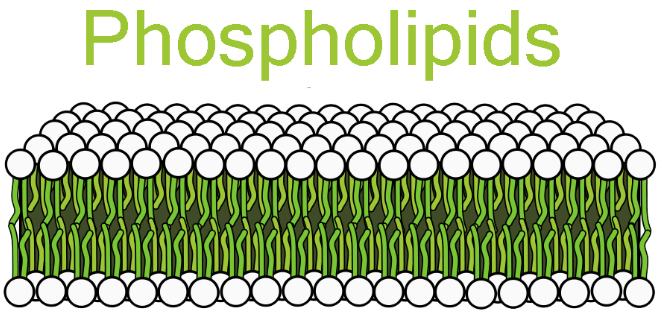


Figure 1.17: Phospholipids in a membrane.

Nucleic acids

Nucleic acids are long chains of nucleotides. Nucleotides are made of a sugar, a nitrogen-containing base, and a phosphate group. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two main nucleic acids. DNA is the molecule that stores our genetic information (**Figure** 1.18). RNA is involved in making proteins. ATP (adenosine triphosphate), known as the ”energy currency” of the cell, is also a nucleic acid. See the National Institutes of Health publication *The New Genetics* (`http://publications.nigms.nih.gov/thenewgenetics)` for further information.

Figure 1.18: DNA, a nucleic acid.

An overview of DNA can be seen at `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/`

4/_-vZ_g7K6P0.

Figure 1.19: DNA (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/101

Arsenic in Place of Phosphorus?

In late 2010, scientists proposed that the notion that the elements essential for life - carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur - may have additional members. Scientists have trained a bacterium to eat and grow on a diet of arsenic, in place of phosphorus. Phosphorus chains form the backbone of DNA, and ATP is the principal molecule in which energy in the cell is stored. Arsenic is directly under phosphorus in the Periodic Table, so the two elements have similar chemical bonding properties. This finding raises the possibility that organisms could exist on Earth or elsewhere in the universe using biochemicals not currently known to exist. These results will expand the notion of what life could be and where it could be. It could be possible that life on other planets may have formed using biochemicals with other elements.

See `http://www.nytimes.com/2010/12/03/science/03arsenic.html?pagewanted=1&#38;_r=3` for further information.

Lesson Summary

- Elements are substances that cannot be broken down into simpler substances with different properties.
- Elements have been organized by their properties to form the periodic table.
- Two or more atoms can combine to form a molecule.
- Molecules consisting of more than one element are called compounds.
- Reactants can combine through chemical reactions to form products.
- Enzymes can speed up a chemical reaction.
- Living things are made of just four classes of macromolecules: proteins, carbohydrates, lipids, and nucleic acids.

Review Questions

Recall

1. What are the 4 main classes of organic compounds?

2. Sugar is what kind of organic compound?

3. What is an atom?

4. Name a few examples of proteins.

5. Name a few examples of lipids in organisms.
6. What are two nucleic acids?

Apply Concepts

7. Would water, with the symbol H_2O, be considered an element or a compound?
8. How many types of atoms make up gold?

Think Critically

9. Why do you think you need fats in your diet?

Points to Consider

- Do you expect the genetic information in the DNA of a cow to be the same or different from that in a crow?
- If we are all composed of the same chemicals, how do all organisms look so different?
- What characteristics would you use to distinguish and classify living things?

1.3 Classification of Living Things

Lesson Objectives

- Explain what makes up a scientific name.
- Explain what defines a species.
- List the information scientists use to classify organisms.
- List the three domains of life and the chief characteristics of each.

Check Your Understanding

- What are the basic characteristics of life?
- What are the four main classes of organic molecules that are building blocks of life?

Vocabulary

Archaea bacteria binomial nomenclature
classify domain Eukarya
genus species taxonomy

Classifying Organisms

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they **classify**, or put in categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears. It turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean system of classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carl Linnaeus (1707-1778) (**Figure** 1.20) built on Aristotle's work to create his own classification system. He invented the way we name organisms today. Linnaeus is considered the inventor of modern **taxonomy**, the science of naming and grouping organisms. See `http://www.ucmp.berkeley.edu/history/linnaeus.html` for additional information.

Linnaeus developed **binomial nomenclature**, a way to give a scientific name to every organism. Each species receives a two-part name in which the first word is the **genus** (a group of species) and the second

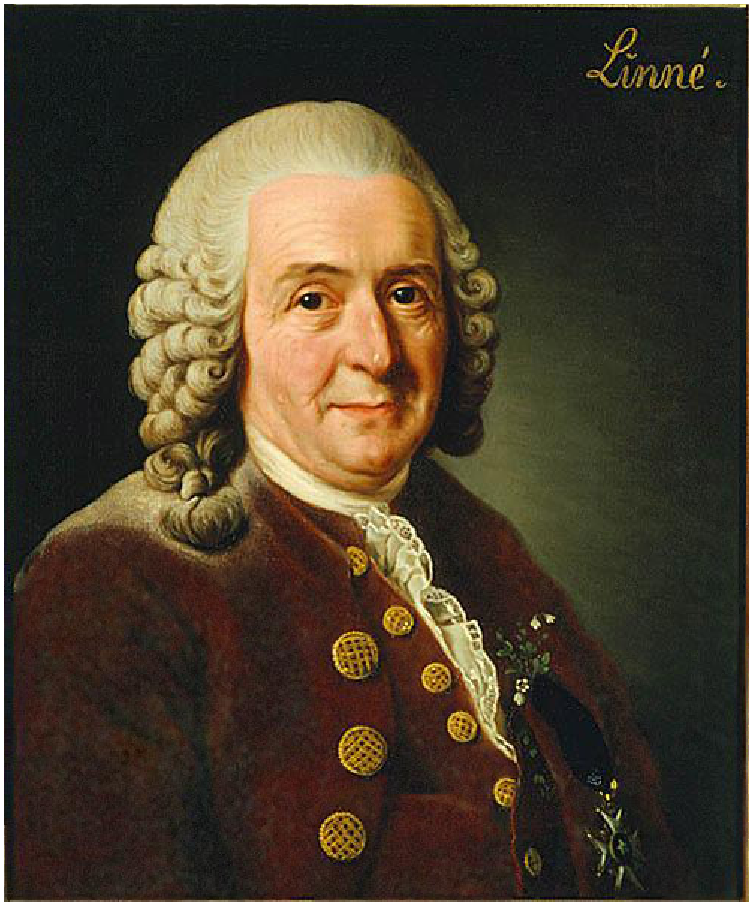


Figure 1.20: In the 18 century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals.

Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum*, are both in the same genus and they look similar (**Figure** 1.21, **Figure** 1.22, and **Figure** 1.23). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. The names may seem strange, but they are written in a language called Latin.

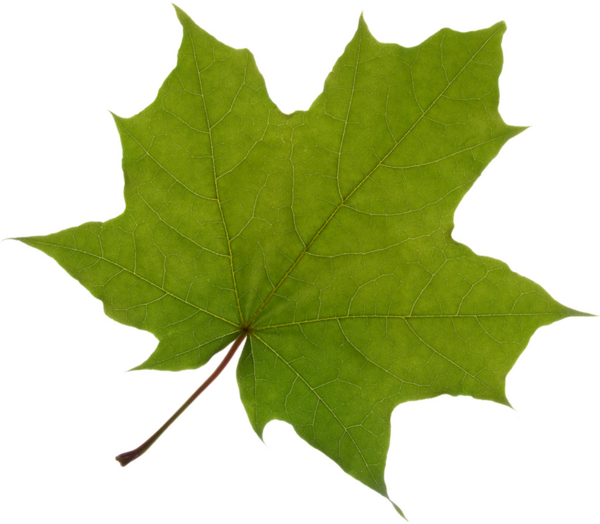


Figure 1.21: These leaves are from one of two different species of trees in the Acer, or maple, genus.

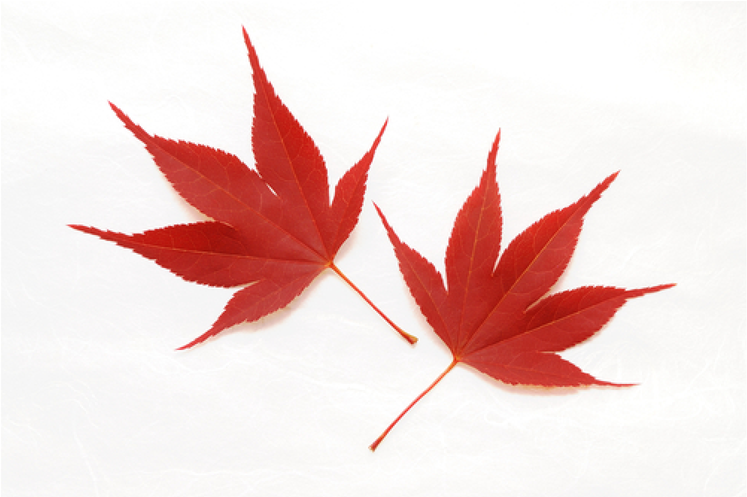


Figure 1.22: These leaves are from one of two different species of trees in the Acer, or maple, genus.

Figure 1.23

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** 1.24). See `http://www.pbs.org/wgbh/nova/orchid/classifying.html` for further information.

- Least Specific
  - Domain
  - Kingdom
  - Phylum
  - Class
  - Order
  - Family
  - Genus
  - Species
- Most Specific

The *Classification Rap* can be heard at `http://www.youtube.com/watch?v=6jAGOibTMuU` (3:18).

Difficulty Naming Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** 1.26).

So how is a species defined? A **species** is group of individuals that can interbreed with one another and produce fertile offspring; a species does not interbreed with other groups. By this definition, two species

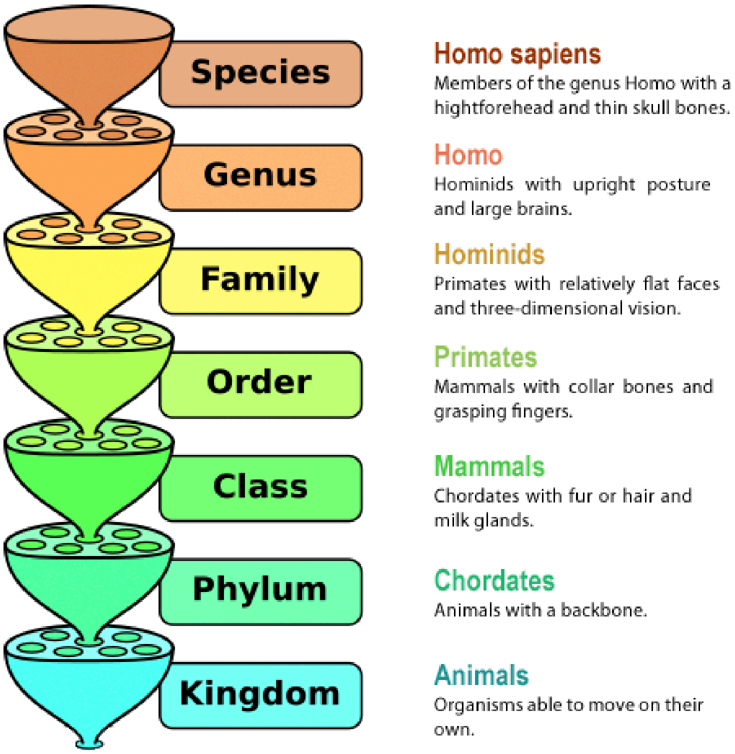

Species
Genus
Family
Order
Class
Phylum
Kingdom
Homo sapiens
Members of the genus Homo with a hightforehead and thin skull bones.
Homo
Hominids with upright posture and large brains.
Hominids
Primates with relatively flat faces and three-dimensional vision.
Primates
Mammals with collar bones and grasping fingers.
Mammals
Chordates with fur or hair and milk glands.
Chordates
Animals with a backbone.
Animals
Organisms able to move on their own.

Figure 1.24: This diagram illustrates the classification categories for organisms, with the broadest category (Kingdom) at the bottom, and the most specific category (Species) at the top.

Video

Figure 1.25: Classification Rap (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/590

of animals or plants that do not interbreed are not the same species. See *Biological Classification of Organisms* for additional information: `http://www.physicalgeography.net/fundamentals/9b.html`.

Figure 1.26: These children are all members of the same species, Homo sapiens.

Domains of Life

Let's explore the least specific category of classification, called a **domain**.

All of life can be divided into 3 domains, which tell you the type of cell inside of an organism:

1. **Bacteria**: Single-celled organisms that do not contain a nucleus
2. **Archaea**: Single-celled organisms that do not contain a nucleus; have a different cell wall from bacteria
3. **Eukarya**: Organisms with cells that contain a nucleus.

Archaea and Bacteria

Archaea and Bacteria (**Figure** 1.27 and **Figure** 1.28) seem very similar, but they also have significant differences.

Similarities:

- Do not have a nucleus
- Small cells
- One-celled
- Can reproduce without sex by dividing in two

Differences:

- Cell walls made of different material
- Archaea often live in extreme environments like hot springs, geysers, and salt flats while bacteria can live almost everywhere.

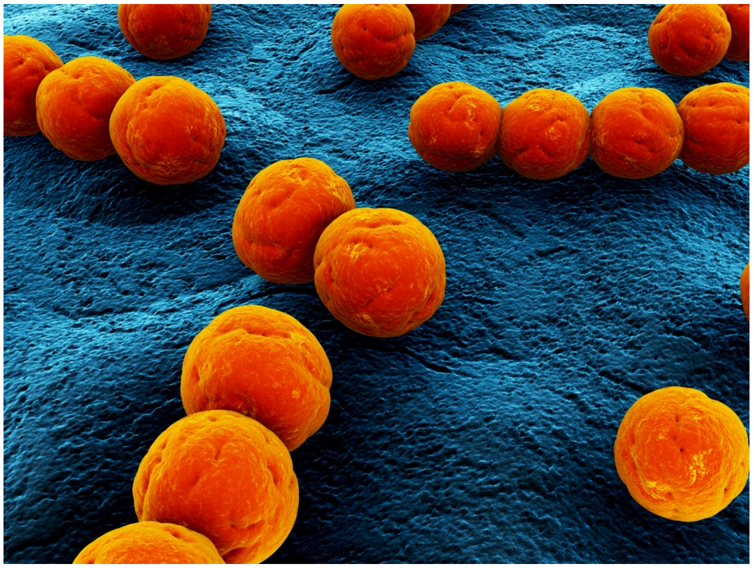


Figure 1.27: The Group D Streptococcus organism is in the domain Bacteria, one of the three domains of life.

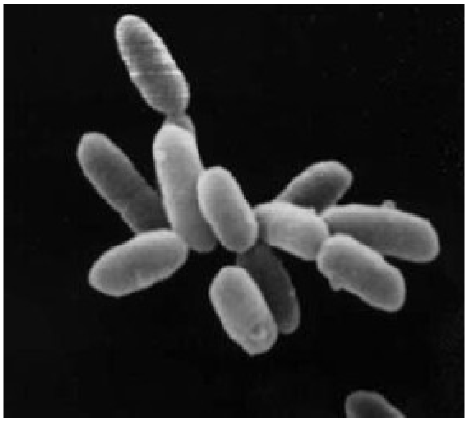


Figure 1.28: The Halobacterium is in the domain Archaea, one of the three domains of life.

Eukarya

All of the cells in the domain Eukarya keep their genetic material, or DNA, inside the nucleus. The domain Eukarya is made up of four kingdoms:

1. Plantae: Plants, such as trees and grasses, survive by capturing energy from the sun, a process called photosynthesis.
2. Fungi: Fungi, such as mushrooms and molds, survive by ”eating” other organisms or the remains of other organisms.
3. Animalia: Animals survive by eating other organisms or the remains of other organisms. Animals range from tiny worms to insects, dogs, and the largest dinosaurs and whales (**Figure** 1.29).
4. Protista: Protists are not all descended from a single common ancestor in the way that plants, animals, and fungi are. Protists are all the eukaryotic organisms that do not fit into one of the other three kingdoms. They include many kinds of microscopic one-celled organisms, such as algae and plankton, but also giant seaweeds that can grow to be 200 feet long (an alga protist is shown in **Figure** 1.30).

Plants, animals, fungi, and protists might seem very different, but remember that if you look through a microscope, you will find similar cells with a membrane-bound nucleus in all of them. The main characteristics of the three domains of life are summarized in **Table** 1.2.

Figure 1.29: The Western Gray Squirrel is in the domain Eukarya, one of the three domains of life.

Table 1.2:

	Archaea	**Bacteria**	**Eukarya**
Multicelluar	No	No	Yes

Table 1.2: (continued)

	Archaea	**Bacteria**	**Eukarya**
Cell Wall	Yes, without peptidoglycan	Yes, with peptidoglycan	Varies. Plants and fungi have a cell wall; animals do not.
Nucleus (DNA inside a membrane)	No	No	Yes
Organelles inside a membrane	No	No	Yes

Viruses

We have all heard of viruses. The flu and many other diseases are caused by viruses. But what is a virus? Based on the material presented in this chapter, do you think viruses are living?

The answer is actually "no." A virus is essentially DNA or RNA surrounded by a coat of protein (**Figure** 1.31). It is not a cell and does not maintain homeostasis. Viruses also cannot reproduce on their own – they need to infect a host cell to reproduce. Viruses do, however, change over time, or evolve. So a virus is very different from any of the organisms that fall into the three domains of life.

Lesson Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.
- Scientists classify organisms according to their evolutionary histories and how related they are to one another - by looking at their physical features, the fossil record, and DNA sequences.
- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.

Review Questions

Recall

1. Who designed modern classification and invented the two-part species name?
2. Define a species.
3. What kingdoms make up the domain Eukarya?
4. What is the name for the scientific study of naming and classifying organisms?
5. How are organisms given a scientific name?

Apply Concepts

6. In what domain are humans?
7. *Quercus rubra* is the scientific name for the red oak tree. What is the red oak's genus?
8. In what domain are mushrooms?

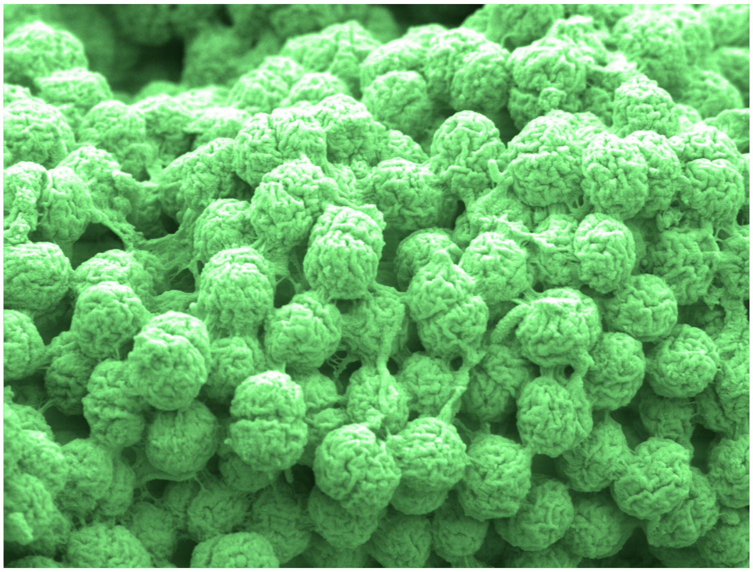


Figure 1.30: This microscopic alga is a protist in the domain Eukarya.

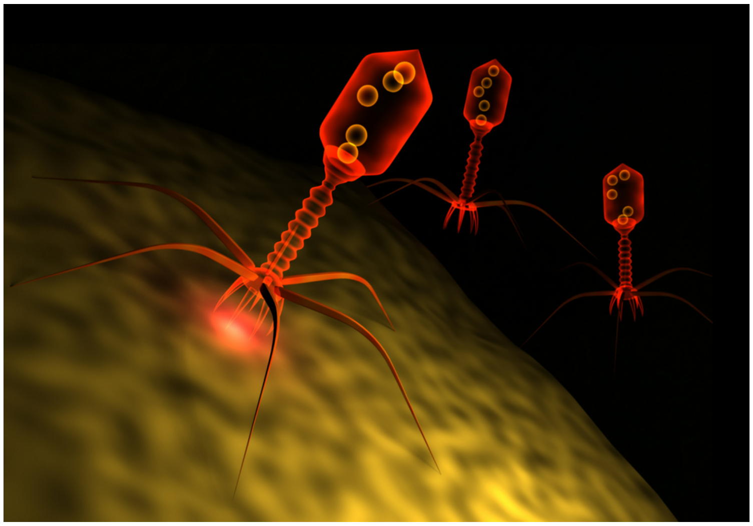


Figure 1.31: These “moon lander” shaped viruses infects bacteria.

9. What information do scientists use to classify organisms?

Think Critically

10. Is it possible for organisms in two different classes to be in the same genus?

11. If molecular data suggests that two organisms have very similar DNA, what does that say about their evolutionary relatedness?

12. Can two different species ever share the same scientific name?

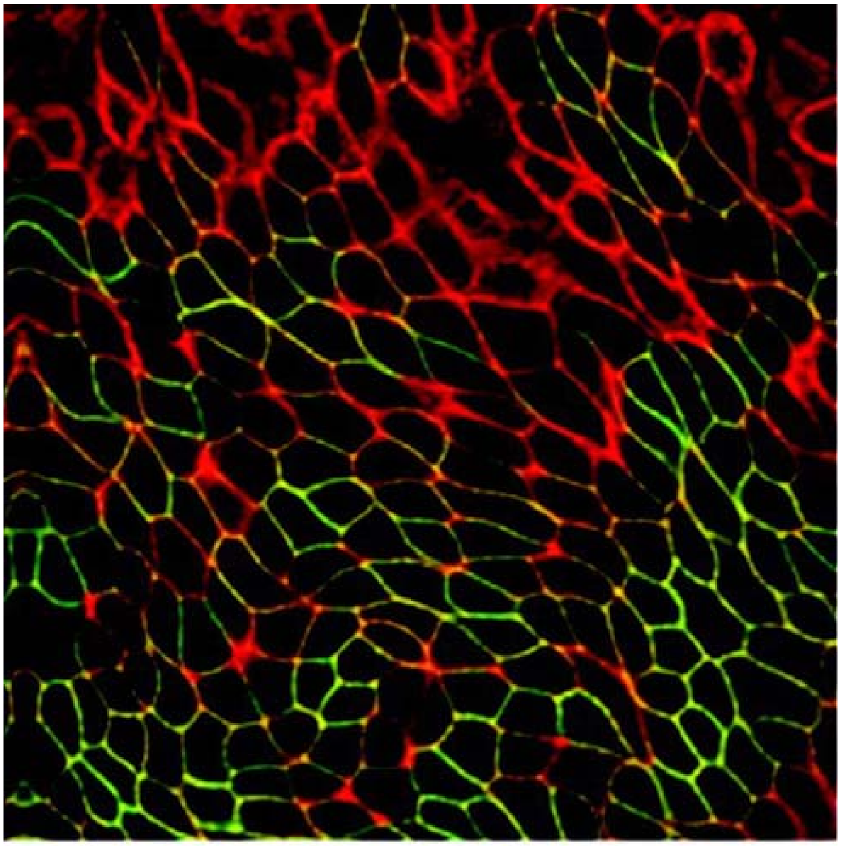
13. If two organisms are in the same genus, would you expect them to look much alike?

Points to Consider

- This Section introduced the diversity of life on Earth. Do you think it is possible for cells from different organisms to be similar even though the organisms look different?
- Do you think human cells are different from bacterial cells?
- Do you think it is possible for a single cell to be a living organism?

Chapter 2

MS Cells and Their Structures



Look carefully at the above image. What do you see? What colors? What shapes? Can you guess what it is?

These are actually cells from a dog's kidney. Cells are the smallest units of living things. You are made of cells. Plants are made of cells. So are dogs, chickens, bees and mushrooms. Our cells even look very similar to the above dog cells.

But the cells of a kidney are not actually bright green and red. Scientists remove cells from organisms, dye them with different colors, and look at them under strong microscopes. The above image is an example of what scientists see under these microscopes. Now, we will explore what different types of cells look like and what they do.

2.1 Introduction to Cells

Lesson Objectives

- Explain how cells are observed.
- Define the three main parts of the cell theory.
- Explain the levels of organization in an organism.

Check Your Understanding

- What are the five main characteristics of living things?
- Name the four main classes of organic molecules that are building blocks of life.

Vocabulary

organ organ system tissue

What are cells?

In the chapter *What is a Living Organism?*, you learned that living things are made of big molecules called proteins, lipids, carbohydrates, and nucleic acids. When these big molecules come together, they form a cell. A **cell** is the smallest unit of an organism that is still considered living (see the onion cells in **Figure** 2.1). Some organisms, like bacteria, consist of only one cell. Big organisms, like humans, consist of trillions of cells. Compare a human to a banana. On the outside, they look very different, but if you look close enough you'll see that their cells are actually very similar.

The Inner Life of the Cell can be viewed at `http://www.youtube.com/watch?v=Mszlckmc4Hw` (5:28).

Observing Cells

Most cells are so tiny that you cannot see them without the help of a microscope. It was not until 1665 that English scientist Robert Hooke invented a basic light microscope and observed cells for the first time. You may use light microscopes in the classroom. You can use a light microscope to see cells. But many structures in the cell are too small to see with a light microscope. So, what do you do if you want to see the tiny structures inside of cells?

In the 1950s, scientists developed more powerful microscopes. A light microscope sends a beam of light through a **specimen**, or the object you are studying. A more powerful microscope, called an **electron microscope**, passes a beam of electrons through the specimen. Sending electrons through a cell allows us to see its tiniest parts (**Figure** 2.3).

Without electron microscopes, we would not know what the inside of a cell looked like. The only problem with using an electron microscope is that it only works with dead cells. Scientists and students still use

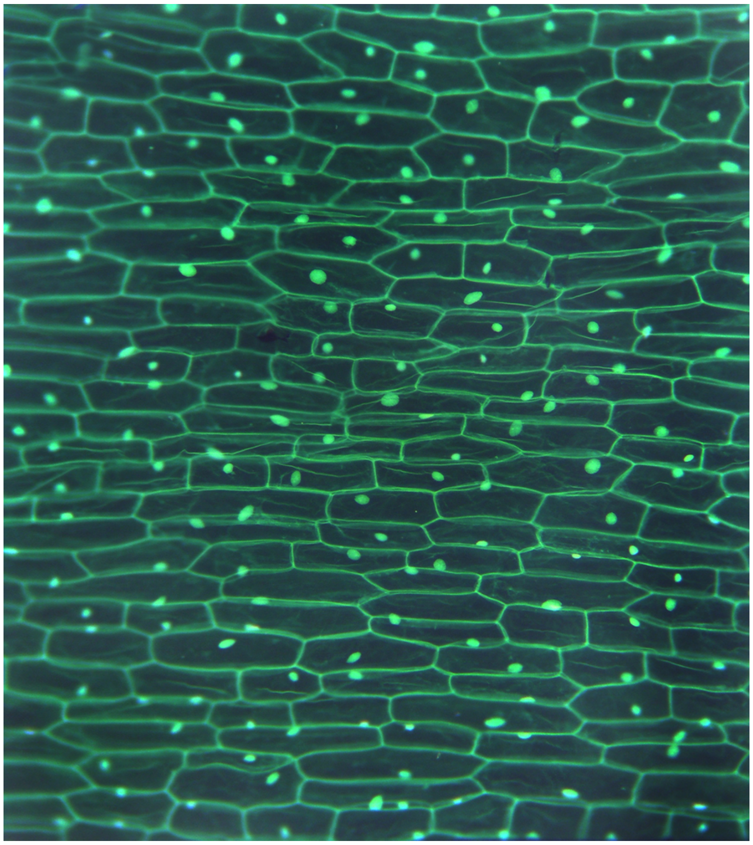


Figure 2.1: The outline of onion cells are visible under a light microscope.

Video

Figure 2.2: The Inner Life of the Cell (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/588

light microscopes to study living cells.

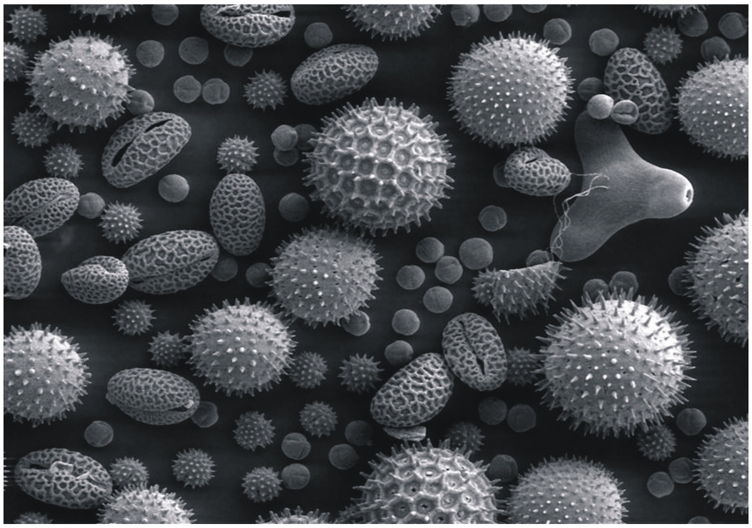


Figure 2.3: An electron microscope allows scientists to see much more detail than a light microscope, as with this sample of pollen. But a light microscope allows scientists to study living cells.

How to Correctly Use a Microscope can be viewed at `http://www.youtube.com/watch?v=jP9HtcAvGDk&#38;feature=related` (1:43).

Video

Figure 2.4: How to Correctly Use a Microscope (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/591

Cell Theory

In 1858, after using microscopes much better than Hooke's first microscope, Rudolf Virchow developed the hypothesis that cells only come from other cells. For example, bacteria are composed of only one cell (**Figure** 2.5) and divide in half to make new bacteria. In the same way, your body makes new cells by dividing the cells you already have. In all cases, cells only come from cells that have existed before. This idea led to the development of one of the most important theories in biology, cell theory.

Cell theory states that:

1. All organisms are composed of cells.
2. Cells are alive and the basic living units of organization in all organisms.
3. All cells come from other cells.

As with other scientific theories, many hundreds, if not thousands, of experiments support the cell theory. Since Virchow created the theory, no evidence has ever contradicted it.

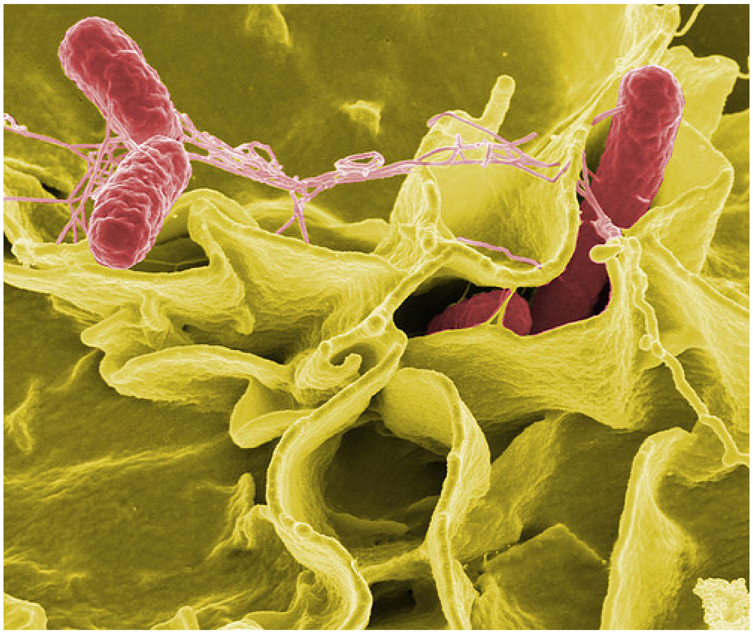


Figure 2.5: Bacteria (pink) are an example of an organism consisting of only one cell.

Levels of Organization

Although cells share many of the same features and structures, they also can be very different. Each cell in your body is designed for a specific task.

For example:

- Red blood cells (**Figure** 2.6) are shaped with a pocket that traps oxygen and brings it to other body cells.
- Nerve cells, which can quickly send the feeling of touching a hot stove to your brain, are long and stringy in order to form a line of communication with other nerve cells, like a wire (**Figure** 2.7).
- Skin cells (**Figure** 2.8) are flat and fit tightly together to protect your body.

An animation comparing the size of red blood cells and skin cells to other structures can be found at `http://learn.genetics.utah.edu/content/begin/cells/scale/.`

As you can see, cells are shaped in ways that help them do their jobs. Multicellular (many-celled) organisms have many types of specialized cells in their bodies.

While cells are the basic units of an organism, groups of cells can be specialized, or perform a specific job. Specialized cells can be organized into tissues. For example, your liver cells are organized into liver tissue, which is organized into an organ, your liver. Organs are formed from two or more specialized tissues working together to perform a job that helps your body work. All organs, from your heart to your liver, are made up of an organized group of tissues.

These organs are part of a larger system, the organ systems. For example, your brain works together with your spinal cord and other nerves to form the nervous system. This organ system must be organized with other organ systems, such as the circulatory system and the digestive system, for your body to work. Organ

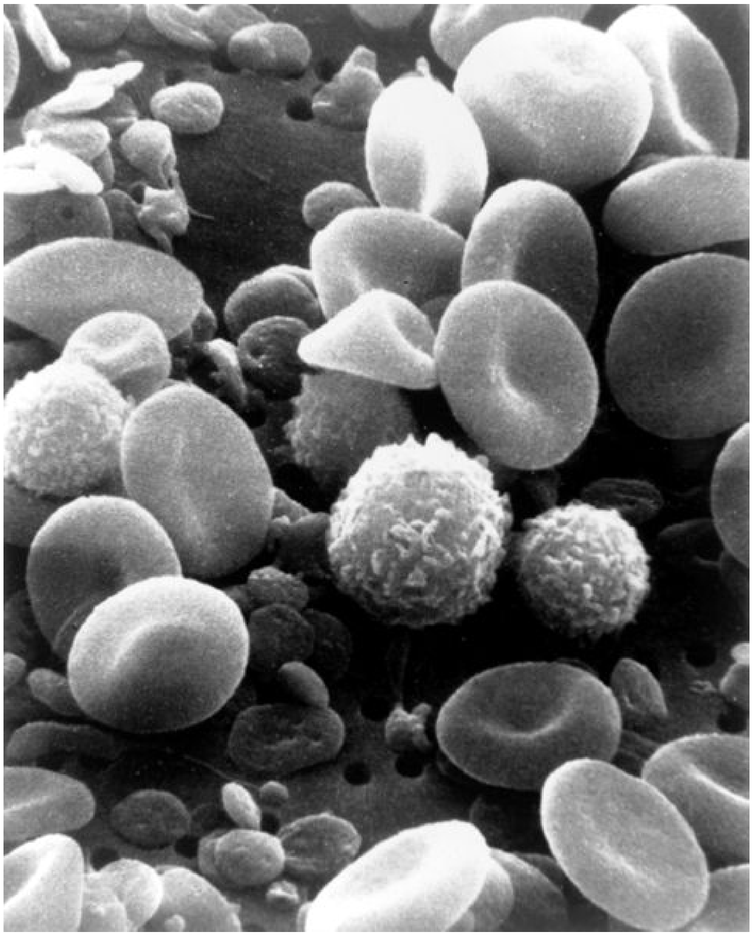


Figure 2.6: Red blood cells are specialized to carry oxygen in the blood.

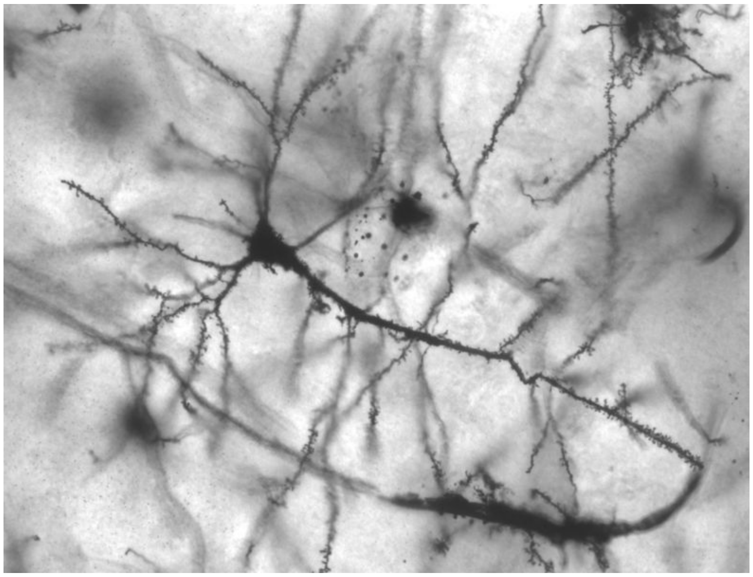


Figure 2.7: Neurons are shaped to conduct electrical impulses to many other nerve cells.

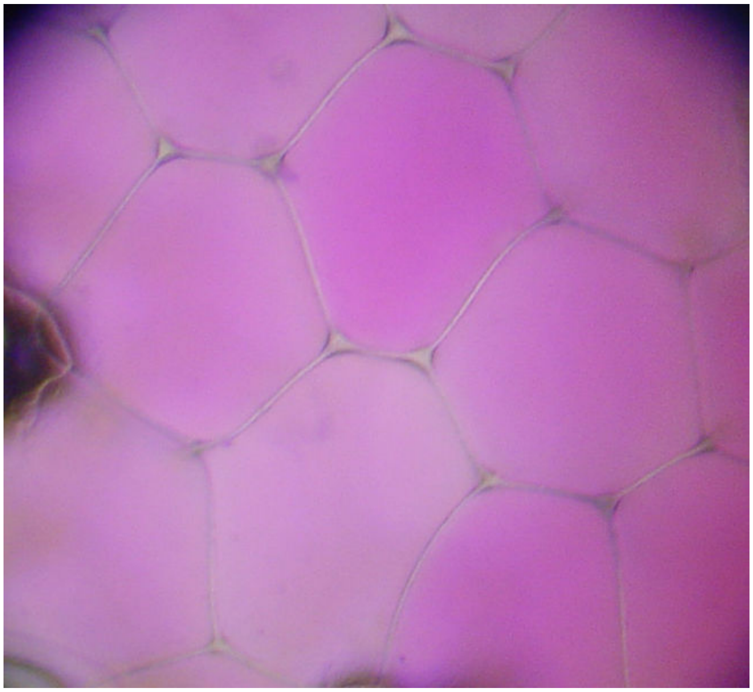


Figure 2.8: These epidermal cells make up the "skin" of plants. Note how the cells fit tightly together.

systems work together to form the entire organism. As you can see (**Figure** 2.9), there are many levels of organization in living things. See `http://www.schools.utah.gov/curr/science/sciber00/7th/cells/sciber/levelorg.htm` for additional information.

Lesson Summary

- Cells were first observed under a light microscope, but today's electron microscopes allow scientists to take a closer look at the inside of cells.
- Cell theory says that:
  - All organisms are composed of cells;
  - Cells are alive and the basic living units of organization in all organisms; and
  - All cells come from other cells.
- Cells are organized into tissues, which are organized into organs, which are organized into organ systems, which are organized to create the whole organism.

Review Questions

Recall

1. What scientific tool was used to first observe cells?
2. What are the three main parts of the cell theory?

Apply Concepts

3. Put the following in the correct order from simplest to most complex: organ, cell, tissue, organ system.

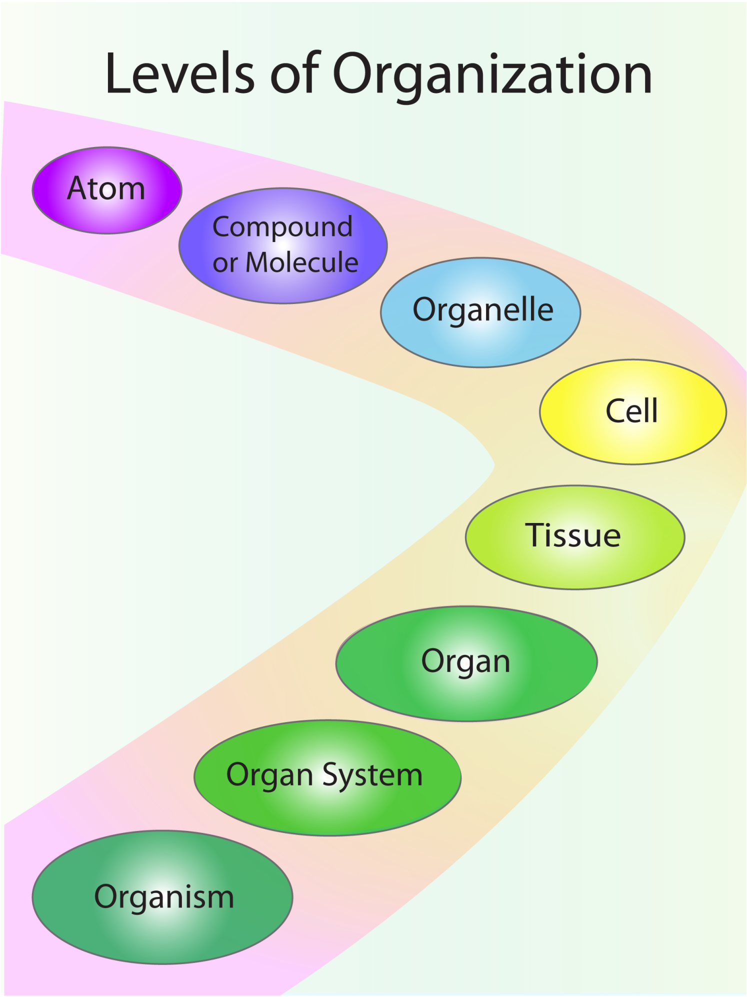


Figure 2.9: Levels of Organization, from the atom to the organism.

4. What type of microscope would be best for studying the structures found inside of cells?

Think Critically

5. According to the cell theory, can we create a new cell in laboratory by putting different molecules together? Why or why not?

Further Reading / Supplemental Links

- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.
- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.

Points to Consider

- Do you think there would be a significant difference between bacterial cells and your brain cells? What might they be?
- Do you think a bacterial cell and a brain cell have some things in common? What might they be?
- Do you think cells have organs like we do? How would that benefit cells?

2.2 Cell Structures

Lesson Objectives

- Compare prokaryotic and eukaryotic cells.
- List the organelles of the cell and their functions.
- Discuss the structure and function of the cell membrane and cytosol.
- Describe the structure and function of the nucleus.
- Distinguish between plant and animal cells.

Check Your Understanding

- What is a cell?
- How do we visualize cells?

Vocabulary

cell wall central vacuole chloroplast
chromosome cytoplasm cytoskeleton
cytosol endoplasmic reticulum (ER) eukaryote
golgi apparatus lysosome mitochondria
nuclear envelope nucleus organelle
plasma membrane prokaryote ribosome
rough endoplasmic reticulum semipermeable
smooth endoplasmic reticulum vesicle

Prokaryotic and Eukaryotic Cells

There are two basic types of cells, prokaryotic cells (**Figure** 2.10), found in organisms called **prokaryotes**, and eukaryotic cells (**Figure** 2.11), found in organisms called **eukaryotes**.

The main difference between eukaryotic and prokaryotic cells is that eukaryotic cells have a **nucleus**, where they store their DNA, or genetic material. The nucleus is membrane-bound, which means it is surrounded by a phospholipid membrane. Prokaryotic cells do not have a ”membrane-bound” nucleus. Instead, their DNA floats around inside the cell.

Here are some other key features of eukaryotic cells:

1. They have membrane-bound structures called **organelles**. A list of the main eukaryotic organelles is located in **Table** 2.2.
2. Eukaryotic cells include the cells of fungi, animals, protists, and plants.
3. These cells are more specialized than prokaryotic cells.

Key features of prokaryotic cells include:

1. The cells are usually smaller and simpler than eukaryotic cells.

2. Prokaryotic cells do not have membrane-bound structures.
3. The DNA, or genetic material, forms a single large circle that coils up on itself.
4. Prokaryotic cells belong to the domains Bacteria or Archaea. These two domains were discussed in the *What is a Living Organism?* chapter.

From the above information, are the cells found in your body prokaryotic cells or eukaryotic cells? **Table** 2.1 compares prokaryotic and eukaryotic cells.

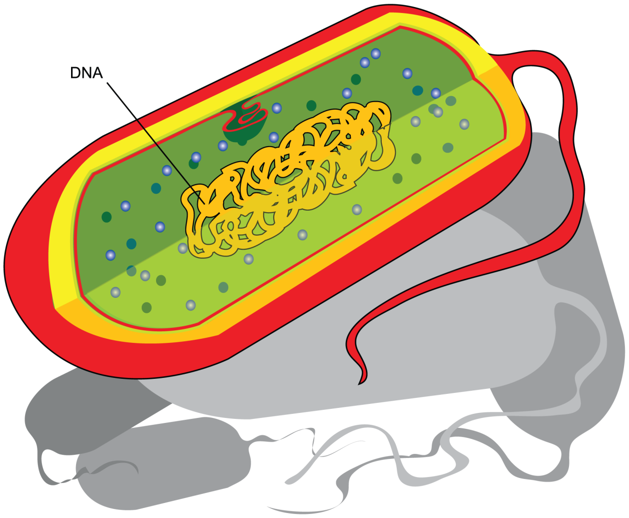


Figure 2.10: Prokaryotes do not have a nucleus. Instead, their genetic material is a simple loop of DNA.

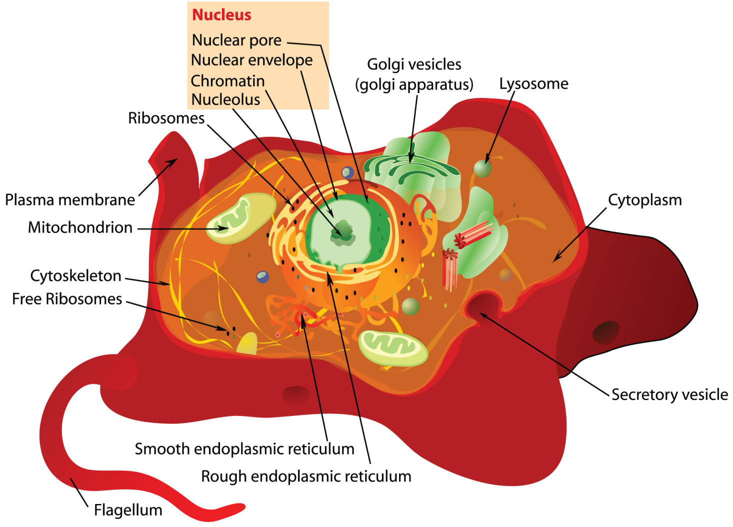


Figure 2.11: Eukaryotic cells contain a nucleus (where the DNA lives, and surrounded by a membrane) and various other special compartments surrounded by membranes, called organelles. For example, notice in this image the mitochondria, lysosomes, and peroxisomes.

Table 2.1: **Comparison of Prokaryotic and Eukaryotic Cells**

Feature	Prokaryotic cells	Eukaryotic cells
DNA	Single "naked" circle; plasmids	In membrane-enclosed nucleus
Membrane-enclosed organelles	No	Yes
Examples	Bacteria	Plants, animals, fungi

An *Introduction to Prokaryotic and Eukaryotic Cells* can be viewed at `http://www.youtube.com/watch?v=nP9lZG94DOO` (2:13)

Figure 2.12: Prokaryotic and Eukaryotic Cells (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/592

The Plasma Membrane and Cytosol

Both eukaryotic and prokaryotic cells have walls around them that separate them from other cells and make sure the parts of the cell do not just float away. This wall is called a plasma membrane. The **plasma membrane** is made of a double layer of lipids, known as phospholipids. The function of the plasma membrane, also known as the cell membrane, is to control what goes in and out of the cell.

Some molecules can go through the cell membrane and enter and leave the cell, but some cannot. ”Permeable” means that anything can cross a barrier. An open door is completely permeable to anything that wants to enter or exit through the door. The plasma membrane is **semipermeable,** meaning that some things can enter the cell and some things cannot.

The inside of eukaryotic and prokaryotic cells also both contain a jelly-like substance called **cytosol**. Cytosol is composed of water and other molecules, including enzymes that speed up the cell's chemical reactions. Everything in the cell - the nucleus and the organelles - sit in the cytosol, like fruit in a Jell-o mold. The term **cytoplasm** refers to the cytosol and all of the organelles, but not the nucleus.

Table 2.2: **Some Eukaryotic Organelles**

Organelle	Function
Ribosomes	Involved in making proteins
Golgi apparatus	Packages proteins and some polysaccharides
Mitochondria	Where ATP is made
Smooth Endoplasmic Reticulum	Makes lipids
Chloroplast	Makes sugar (photosynthesis)
Lysosomes	Digests macromolecules

The Nucleus

The nucleus is only found in eukaryotic cells. It is a membrane-bound structure that contains most of the genetic material of the cell (**Figure** 2.13). The nucleus contains important information that helps the cell create important molecules for life. The **nuclear envelope**, a double membrane that surrounds the nucleus, controls which molecules go in and out of the nucleus.

Inside of the nucleus, you will find the chromosomes. **Chromosomes** are strands of DNA wrapped around proteins. They contain genes, or small units of genetic material that create proteins.

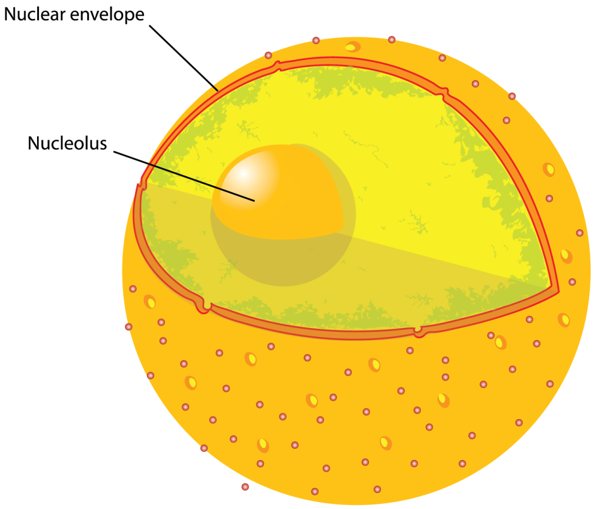


Figure 2.13: In eukaryotic cells, the DNA is kept in a nucleus. The nucleus is surrounded by a double plasma membrane called the nuclear envelope. Within the nucleus is the (smaller yellow ball).

Organelles in the Cytoplasm: The Cell Factory

A cell is like a factory. Just as a factory is made up of many people and machines, a cell has many different parts, each with a special role. The different parts of the cell are called **organelles**, which means ”small organs.” All organelles are found in eukaryotic cells, but most are NOT found in prokaryotic cells. Pay attention to which ones are included in prokaryotic cells.

Below are the main organelles found in cells:

1. The nucleus of a cell is like a safe containing the factory’s trade secrets, including information about how to build thousands of proteins.
2. The **mitochondria** are powerhouses that create ATP (adenosine triphosphate), which provides the energy needed to power chemical reactions. Plant cells have special organelles called **chloroplasts** that capture energy from the sun and store it in the bonds of sugar molecules, using a process called photosynthesis (**Figure** 2.14). (The cells of animals and fungi do not photosynthesize and do not have chloroplasts.)
3. The **vacuoles** are like storage centers. Plant cells have larger ones than animal cells because they need to store water and other nutrients.

4. The **lysosomes** are like the recycling trucks that carry waste away from the factory. Inside lysosomes are enzymes that break down old molecules into parts that can be recycled into new ones.
5. Eukaryotic cells also contain a skeleton-like structure called the **cytoskeleton**. Like our bony skeleton, a cell's cytoskeleton gives the cell its shape and helps the cell to move. What part of a factory would act like a cytoskeleton?
6. In both eukaryotes and prokaryotes, **ribosomes** are where proteins are made. Ribosomes are like the machines in the factory that produce the factory's main product. Proteins are the main product of the cell.
7. Some ribosomes can be found on folded membranes called the endoplasmic reticulum (ER). If the ER is covered with ribosomes, it looks bumpy and is called **rough endoplasmic reticulum**. If the ER does not contain ribosomes, it is smooth and called the **smooth endoplasmic reticulum**. Proteins are made on the rough ER. Lipids are made on the smooth ER.
8. The **Golgi apparatus**, works like a mail room. The Golgi apparatus receives the proteins from the rough ER, puts "shipping addresses" on the proteins, packages them up in vesicles, and then sends them to the right place in the cell.

You can watch an interactive animation of plant and animal cells at the following link: `http://www.cellsalive.com/cells/cell_model.htm.`

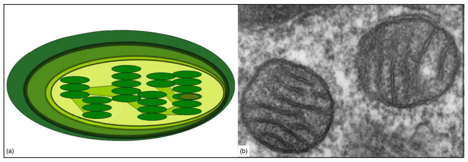


Figure 2.14: Diagram of chloroplast (a) and electron microscope image of two mitochondria (b). Chloroplasts and mitochondria provide energy to cells. If the bar at the bottom of the electron micrograph image is 200 nanometers, what is the diameter of one of the mitochondria?

Differences between Plant and Animal Cells

Even though plants and animals are both eukaryotes, plant cells differ in some ways from animal cells. First, plant cells have a large central vacuole that holds a mixture of water, nutrients, and wastes. A plant cell's vacuole can make up 90% of the cell's volume. In animal cells, vacuoles are much smaller.

Second, plant cells have a cell wall, while animal cells do not. A **cell wall** gives the plant cell strength and protection.

A third difference between plant and animal cells is that plants have several kinds of organelles called **plastids**. There are several kinds of plastids, including chloroplasts, needed for photosynthesis; **leucoplasts**, which store starch and oil; and brightly colored **chromoplasts**, which give some flowers and fruits their yellow, orange, or red color. You will learn more about chloroplasts and photosynthesis in the chapter titled *Cell Functions*. Under a microscope one can see plant cells more clearly (**Figure** 2.15 and **Figure** 2.16).

Lesson Summary

- Prokaryotic cells lack a nucleus; eukaryotic cells have a nucleus.
- Each component of a cell has a specific function.
- Plant cells are different from animal cells. For example, plant cells contain plastids, cell walls, and large vacuoles.

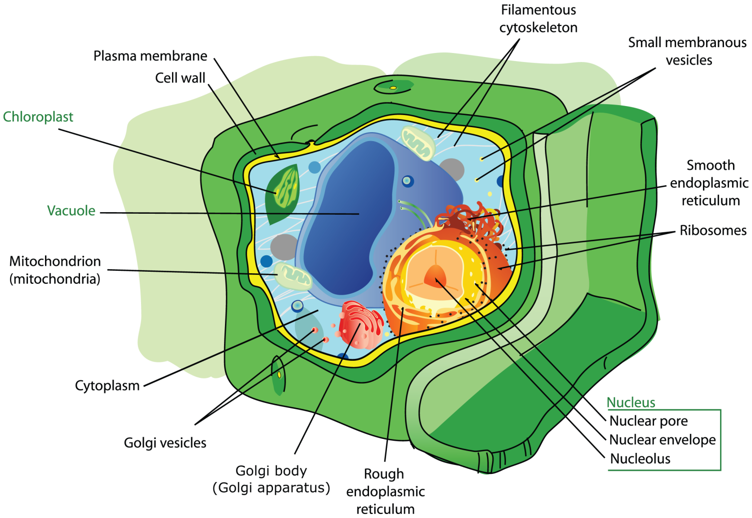


Figure 2.15: A plant cell has several features that make it different from an animal cell, including a cell wall, huge vacuoles, and several kinds of plastids, including chloroplasts (which photosynthesize).

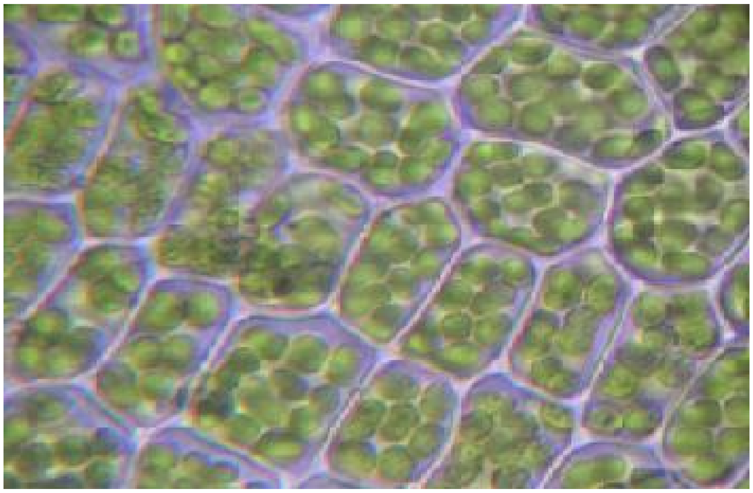


Figure 2.16: In this photo of plant cells taken with a light microscope, you can see a cell wall (purple) around each cell and green chloroplasts.

Review Questions

Recall

1. What are the two basic types of cells?
2. What are organelles?
3. Discuss the main differences between prokaryotic cells and eukaryotic cells.

Apply Concepts

4. What is the plasma membrane and what is its role?
5. Why is the mitochondria known as the powerhouse of the cell?

Think Critically

6. Why does photosynthesis not occur in animal cells?

Further Reading / Supplemental Links

- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.
- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.

Points to Consider

- Think about what molecules would need to be transported into cells.
- Discuss why you think it would be important for some molecules to be kept out of a cell.

Image Sources

(1) NCI. http://commons.wikimedia.org/wiki/File:SEM_blood_cells.jpg. Public Domain.

(2) CK-12 Foundation. *http://commons.wikimedia.org/wiki/Image:Mitochondria%2C_mammalian_lung_-_TEM_%282%29.jpg*. Public Domain.

(3) Nutloaf. http://www.flickr.com/photos/83371410@N00/1644090403/. CC-BY 2.0.

(4) http://commons.wikimedia.org/wiki/Image:Animal_cell_structure.svg. Public Domain.

(5) Dartmouth Electron Microscope Facility. http://commons.wikimedia.org/wiki/File:Misc_pollen.jpg. Public Domain.

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(12) http://commons.wikimedia.org/wiki/Image:Pyramidal_hippocampal_neuron_40x.jpg. CC-BY-SA 2.5.

(13) http://commons.wikimedia.org/wiki/Image:Plant_cell_structure_svg.svg. Public Domain.

Chapter 3

MS Cell Functions

Multi-celled organisms, like dolphins, are made up of trillions of cells. How do you think they work together to move an organism? How do the cells of a tree allow it to absorb water and produce leaves? How are the cells interacting with the world inside of the body and outside of the body? Do small one-celled organisms function the same way as the cells in big organisms like dolphins? We need to know how cells function, so we can understand how entire organisms, both large and small, function.

3.1 Transport

Lesson Objectives

- Describe methods of transporting molecules into and out of the cell.
- Distinguish between active and passive transport.
- Explain how diffusion and osmosis work.

Check Your Understanding

- What structure surrounds the cell?
- What is the primary part of the cell membrane?
- What does homeostasis mean?

Vocabulary

active transport concentration diffusion
hypertonic solution hypotonic solution isotonic solution
osmosis passive transport phospholipid
selectively permeable

Introduction

Cells are found in all different types of environments, and these environments are constantly changing. One-celled organisms, like bacteria, can be found on your skin, or in the ground, or in all different types of water. The cells of your body interact with the food you eat, and also with other cells in your body. All cells need a way to protect themselves. This job is done by the cell membrane.

The cell membrane is semipermeable, or **selectively permeable**, which means that only some molecules can get through the membrane. If the cell membrane were completely permeable, the inside of the cell would be the same as the outside of the cell. It would be impossible for the cell to maintain homeostasis. Homeostasis means maintaining a stable internal environment. For example, if your body cells have a temperature of 98.6 degrees F, and it is freezing outside, your cells will maintain homeostasis if the temperature of the cells stays the same and does not drop.

How does the cell ensure it is semipermeable? How does the cell control what molecules enter and leave the cell? The ways that cells control what passes through the cell membrane will be the focus of this lesson.

What is Transport?

Molecules in the cell membrane allow it to be semipermeable. The membrane is made of a double layer of phospholipids (a ”bilayer”) and proteins (**Figure** 3.1). A single phospholipid molecule has two parts:

1. A head that is **hydrophilic**, or water-loving.
2. A tail that is **hydrophobic**, or water-fearing.

There is water found on both the inside and the outside of cells. Since hydrophilic means water-loving and they want to be near water, the heads face the inside and outside of the cell where water is found. The water-fearing, hydrophobic tails face each other in the middle of the cell membrane because water is not found in this space. An interesting quality of the plasma membrane is that it is constantly moving, like a soap bubble. Water and small molecules such as oxygen and carbon dioxide can pass freely through the membrane, but larger molecules cannot easily pass through the plasma membrane. Some molecules need a special way to get across the membrane.

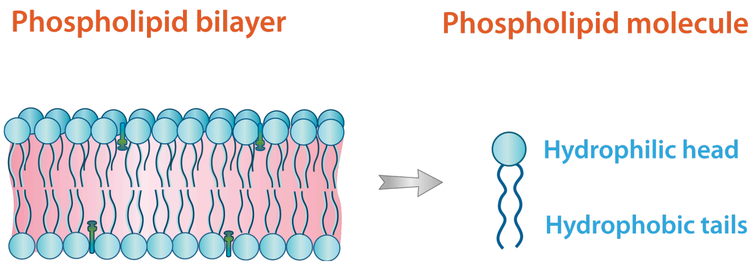


Figure 3.1: The cell membrane is made up of a phospholipid bilayer, two layers of phospholipid molecules.

Diffusion

Small molecules can pass through the plasma membrane through a process called diffusion. **Diffusion** is the movement of molecules from an area where there is a higher concentration (larger amount) of the substance to an area where there is a lower concentration (lower amount) of the substance (**Figure** 3.2). The amount of a substance in relation to the total volume is the **concentration**.

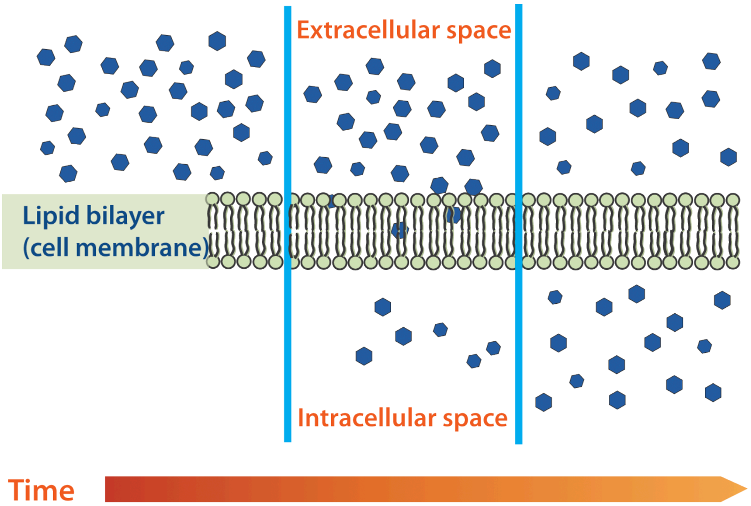


Figure 3.2: Diffusion is the movement of a substance from an area of a higher amount towards an area of lower amount. Equilibrium is reached when there is an equal amount on both sides of the membrane.

The diffusion of water across a membrane because of a difference in concentration is called **osmosis**. Let's explore three different situations and analyze the flow of water.

1. A **hypotonic solution** means the environment outside of the cell has a lower concentration of dissolved material than the inside of the cell. If a cell is placed in a hypotonic solution, water will move into the cell. This causes the cell to swell, and it may even burst.

2. A **hypertonic solution** means the environment outside of the cell has more dissolved material than inside of the cell. If a cell is placed in a hypertonic solution, water will leave the cell. This can cause a cell to shrink and shrivel.
3. An **isotonic solution** is a solution in which the amount of dissolved material is equal both inside and outside of the cell. Water still flows in both directions, but an equal amount enters and leaves the cell.

How do marine animals keep their cells from shrinking? How do blood cells keep from bursting? Both have to do with the cell membrane and transport of materials. Marine animals live in salt water, which is a hypertonic environment; there is more salt in the water than in their cells. To prevent losing too much water from their bodies, these animals intake large quantities of salt water and secrete salt by active transport, which will be discussed later in this lesson. Red blood cells can be kept from bursting or shriveling if put in a solution that is isotonic to the blood cells. If the blood cells were put in pure water, the solution would be hypotonic to the blood cells, so water would enter the blood cells and they would swell and burst. This is represented in **Figure** 3.3.

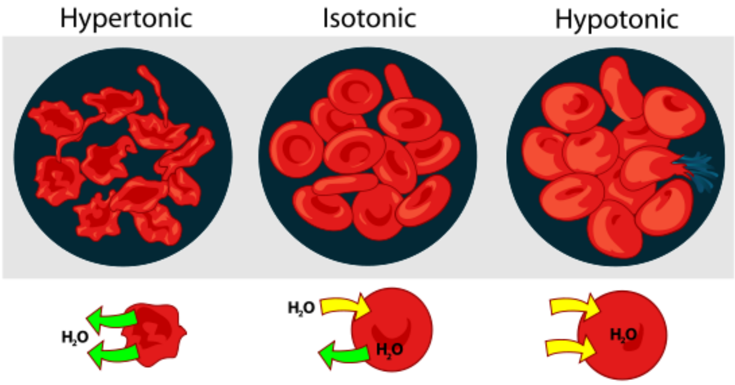


Figure 3.3: Osmosis causes these red blood cells to change shape by losing or gaining water.

Passive Transport

Diffusion is called **passive transport**. This means it does not require energy to move molecules. For example, oxygen diffuses out of the air sacs in your lungs into your bloodstream because oxygen is more concentrated in your lungs than in your blood. Oxygen moves from the high concentration of oxygen in your lungs to the low concentration of oxygen in your bloodstream. Sometimes, special proteins are needed to help molecules move across the membrane. These are called channel proteins or carrier proteins (**Figure** 3.4).

Diffusion Across Cell Membranes: Passive Transport can be viewed at `http://www.youtube.com/watch?v=JShwXBWGMyY` (4:41).

Active Transport

During **active transport,** molecules move from an area of high concentration to low concentration. This is the opposite of diffusion. Active transport is called ”active” because this type of transport requires energy to move molecules. A protein in the membrane carries the molecules across the membrane. These proteins are often called ”pumps”, because like other pumps they use energy to move molecules. There

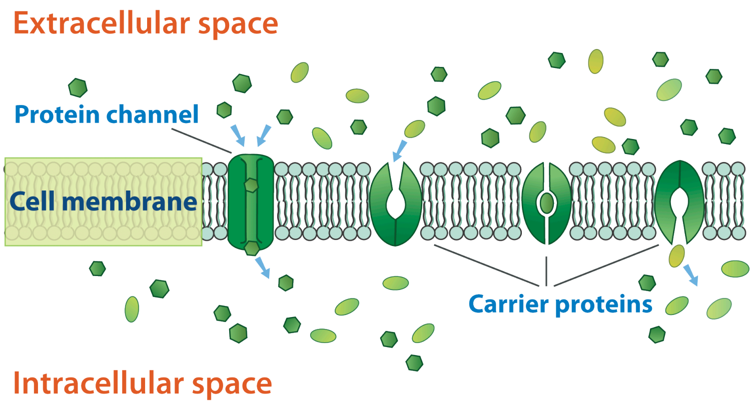


Figure 3.4: Protein channels and carrier proteins are involved in passive transport.

Video

Figure 3.5: Cell Membrane Passive Transport | Cell Biology (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/593

are many cells in your body that use pumps to move molecules. For example, your nerve cells would not send messages to your brain unless you had protein pumps moving molecules by active transport. The sodium-potassium pump (**Figure** 3.7) is an example of an active transport pump.

An overviewof active transport can be viewed at `http://www.youtube.com/watch?v=yz7EHJFDEJs&#38;feature=related` (1:26).

Video

Figure 3.6: active transport.wmv (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/594

Lesson Summary

- The plasma membrane is semipermeable, meaning that some molecules can move through the membrane easily, while others cannot.
- Passive transport, such as diffusion and osmosis, does not require energy.

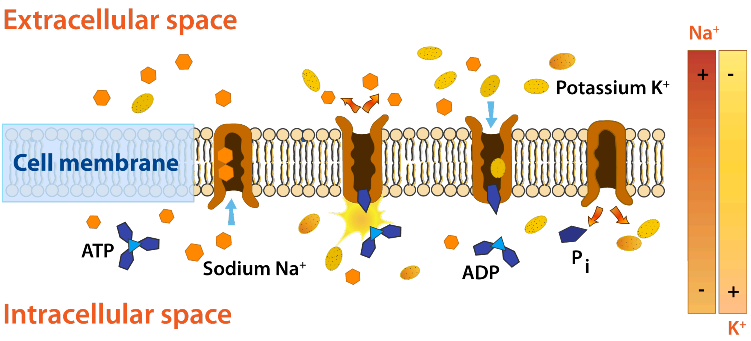


Figure 3.7: The sodium-potassium pump moves sodium ions to the outside of the cell and potassium ions to the inside of the cell. ATP is required for the protein to change shape. As ATP adds a phosphate group to the protein, it leaves behind adenosine diphosphate (ADP).

- Active transport moves molecules in the direction of the higher concentration and requires energy and a carrier protein.

Review Questions

Recall

1. What's the main difference between active and passive transport?
2. List the two types of passive transport.
3. Why is the plasma membrane considered semipermeable?
4. What is diffusion?

Apply Concepts

5. What happens when a cell is placed in a hypotonic solution?
6. What happens when a cell is placed in a hypertonic solution?

Critical Thinking

7. If a plant cell is placed in a solution and the cell shrivels up, what type of solution was it placed in? How do you know?

8. If a there are 100 X molecules on the outside of a cell and 10 X molecules inside of the cell, will X molecules flow into or out of the cell? Explain why.

Points to Consider

The next lesson discusses photosynthesis.

- It is often said that plants make their own food. What do you think this means?
- What substances do you think would need to move into a leaf cell for the cell to make its own food?
- What substances would need to move out of a leaf cell?

3.2 Photosynthesis

Lesson Objectives

- Explain the importance of photosynthesis.
- Write and interpret the chemical equation for photosynthesis.
- Describe what happens during the light reactions and the Calvin Cycle.

Check Your Understanding

- How are plant cells different from animal cells?
- In what organelle does photosynthesis take place?

Vocabulary

chlorophyll photosynthesis stomata
stroma thylakoid

What is Photosynthesis?

If a plant gets hungry, it cannot walk to a local restaurant and buy a slice of pizza. So how does a plant get the food it needs to survive? **Photosynthesis** is the process plants use to make their own “food” from the sun’s energy, carbon dioxide and water.

Actually, almost all organisms obtain their energy from photosynthetic organisms. For example, if a bird eats a caterpillar, then the bird gets the energy that the caterpillar gets from the plants it eats. So the bird is indirectly getting energy that began with the “food” formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth.

During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen. Glucose is a sugar that acts as the ”food” source for plants. Oxygen, which is necessary for animal life, is the waste of photosynthesis.

The Photosynthesis Song can be heard at `http://www.youtube.com/watch?v=C1_uez5WX1o` (1:52).

Figure 3.8: MY FAVE SONG: THE PHOTOSYNTHESIS SONG (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/476

The Process of Photosynthesis

Photosynthesis takes place in chloroplasts. Chloroplasts are one of the main differences between plant and animal cells. There are two separate parts of a chloroplast (**Figure** 3.9).

- The inner compartments formed by the flattened sacs, or **thylakoids,** are called the thylakoid space. Energy from sunlight is absorbed by the pigment chlorophyll in the thylakoid membrane.
- The interior space that surrounds the thylakoids is filled with a fluid called **stroma.** This is where carbon dioxide is used to produce glucose.

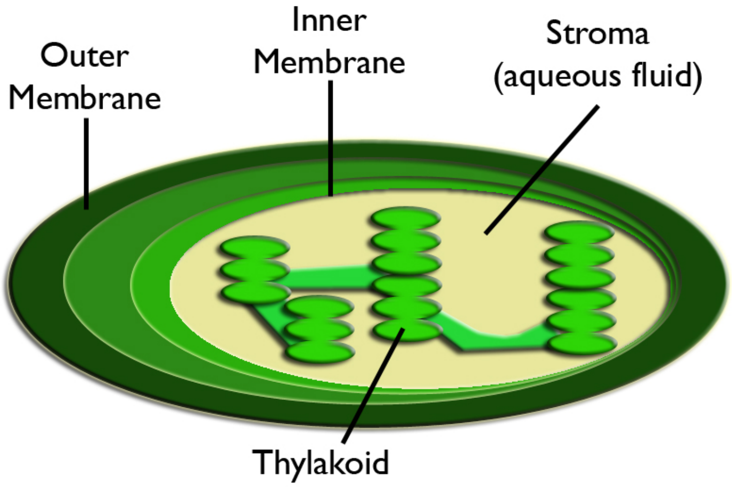


Figure 3.9: The chloroplast is the photosynthesis factory of the plant.

The Reactants

What goes into the plant cell? The reactants of photosynthesis are carbon dioxide and water, and the energy from sunlight. This means that carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.

- **Chlorophyll** is the green pigment in leaves that captures energy from the sun.
- The *veins* in a plant carry water from the roots to the leaves.
- Carbon dioxide enters the leaf from the air through special openings called **stomata** (**Figure** 3.10).

The Products

What is produced by the plant cell? The products of photosynthesis are glucose and oxygen. This means they are produced at the end of photosynthesis.

- Glucose, the food of plants, can be used to store energy for later in the form of carbohydrate molecules.
- Oxygen is a plant waste product. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

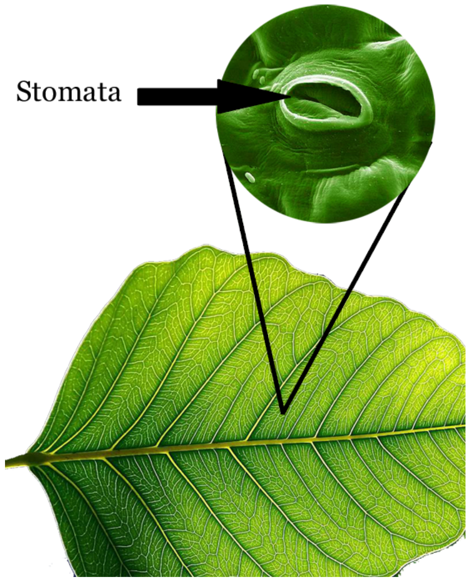


Figure 3.10: Stomata are special pores that allow gasses to enter and exit the leaf.

The Chemical Reaction

The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_20), with the addition of solar energy. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2) (**Figure** 3.11). Using chemical symbols the equation is represented as follows:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

Lesson Summary

- The net reaction for photosynthesis is that carbon dioxide and water, together with energy from the sun, produce glucose and oxygen.

A review of photosynthesis can be viewed at `http://www.youtube.com/watch?v=mpPwmvtDjWw` (2:41).

Review Questions

Recall

1. What are the reactants required for photosynthesis?
2. What are the products of photosynthesis?

Apply Concepts

3. What happens to the glucose produced from photosynthesis?

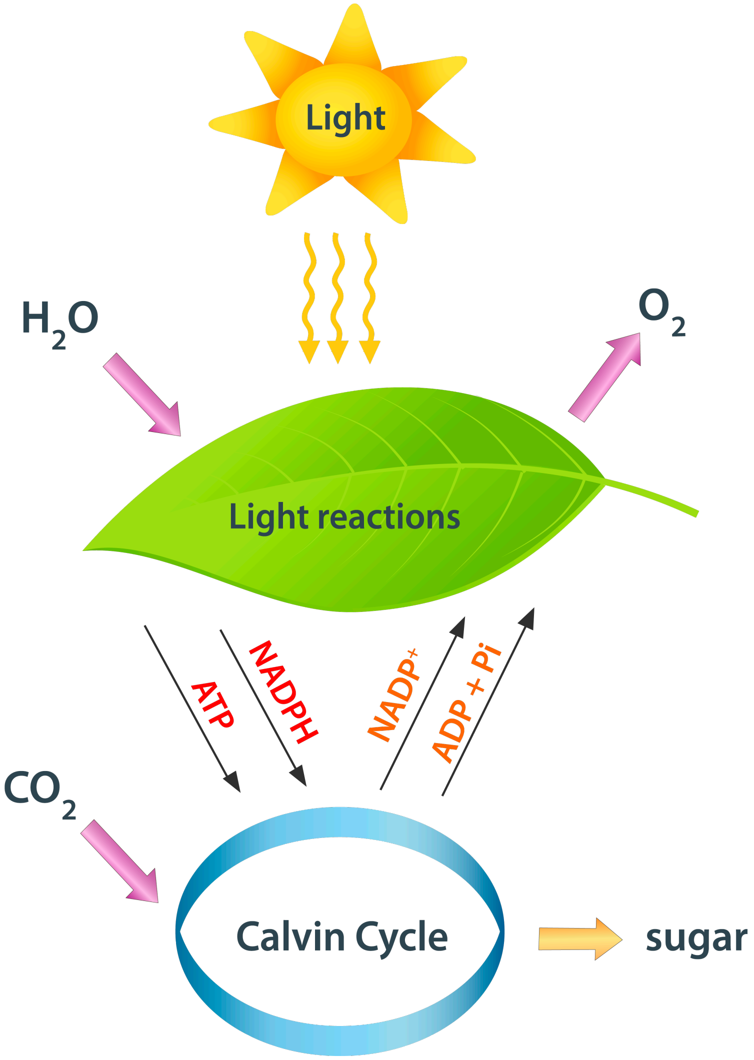


Figure 3.11: As is depicted here, the energy from sunlight is needed to start photosynthesis. The initial steps are called the light reactions as they occur only in the presence of light. During these initial reactions, water is used and oxygen is released. The energy from sunlight is converted into a small amount of ATP and an energy carrier called NADPH. Together with carbon dioxide, these are used to make glucose (sugar) through a process called the Calvin Cycle. NADP+ and ADP (and Pi, inorganic phosphate) are regenerated to complete the process.

Video

Figure 3.12: Photosynthesis (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/595

4. Why is it important to animals that oxygen is released during photosynthesis?

5. Describe the structures of the chloroplast where photosynthesis takes place.

Critical Thinking

6. What would happen if the stomata of a plant leaf were glued shut? Would that plant be able to perform photosynthesis? Why or why not?

Supplemental Links

- Bill Nye the Science Guy discusses plants: http://www.gamequarium.org/dir/SqoolTube_Videos/Science/Plants/bill_nye_on_plants_part_23_7689.html.

Points to Consider

The next lesson is about Cellular Respiration.

- How do you gain energy from the food you eat?
- Which do you think provides more energy- a bowl of pasta or a small piece of candy?
- What "waste" gas do you exhale?

3.3 Cellular Respiration

Lesson Objectives

- Write and explain the chemical formula for cellular respiration.
- Explain the two states of cellular respiration.
- Compare photosynthesis with cellular respiration.

Check Your Understanding

- Where does the energy captured at the beginning of photosynthesis originate from?
- What is the form of chemical energy produced by photosynthesis?
- What occurs in oxidation and reduction reactions?

Vocabulary

aerobic respiration alcoholic fermentation anaerobic respiration
ATP cellular respiration fermentation
lactic acid fermentation

What is Cellular Respiration?

How does the food you eat provide energy? When you need a quick boost of energy, you might reach for an apple or a candy bar. But cells do not "eat" apples or candy bars, these foods need to be broken down so that cells can use them. Through the process of **cellular respiration,** the energy in food is changed into energy that can be used by the body's cells. In other words, glucose and oxygen are converted into ATP, carbon dioxide, and water. **ATP**, or adenosine triphosphate, is chemical energy the cell can use. It is the molecule that provides energy for your cells to perform work, such as moving your muscles as you walk down the street.

A video of cellular respiration can be seen at `http://www.youtube.com/watch?v=nkRcdfmHqqI` (7:58).

Figure 3.13: Respiration 1of3 (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/596

The Process of Cellular Respiration

What happens inside of the cell? Glucose is broken down in the cytoplasm of the cells and then transported to the mitochondria, the organelles known as the energy "powerhouses" of the cells (**Figure** 3.14). Inside the mitochondria, the "broken-down" glucose is broken down again to release ATP. Oxygen is needed to help the process of turning glucose into ATP. The initial step releases just two molecules of ATP for each glucose. The later steps release much more ATP.

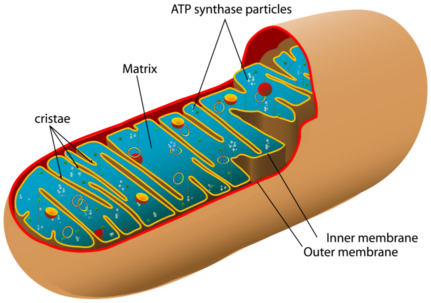


Figure 3.14: Most of the reactions of cellular respiration are carried out in the mitochondria.

The Reactants

What goes into the cell? Oxygen and glucose are both reactants in the process of cellular respiration. Oxygen enters the body when an organism breathes. Glucose enters the body when an organism eats.

The Products

What does the cell produce? The main product of cellular respiration is ATP. Waste products include carbon dioxide and water. Carbon dioxide is transported from your mitochondria out of your cell, to your red blood cells, and back to your lungs to be exhaled.

When one molecule of glucose is broken down, it can be converted to a net total of 36 or 38 molecules of ATP. This only occurs in the presence of oxygen.

The Chemical Reaction

The overall chemical reaction for cellular respiration is 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2) yields 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_20). Using chemical symbols the equation is represented as follows:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Connecting Cellular Respiration and Photosynthesis

Notice that the equation for cellular respiration is the direct opposite of photosynthesis (**Figure** 3.15). While water was broken down to form oxygen during photosynthesis, in cellular respiration oxygen is combined with hydrogen to form water. While photosynthesis requires carbon dioxide and releases oxygen, cellular respiration requires oxygen and releases carbon dioxide. This exchange of carbon dioxide and oxygen in all the organisms that use photosynthesis or cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

Fermentation

Sometimes cellular respiration is **anaerobic**, occurring in the absence of oxygen. In this process, called **fermentation**, no additional ATP is produced, so the organism only obtains the two ATP molecules per glucose molecule from the initial step of this process (compare that to 36-38 ATP produced with oxygen!).

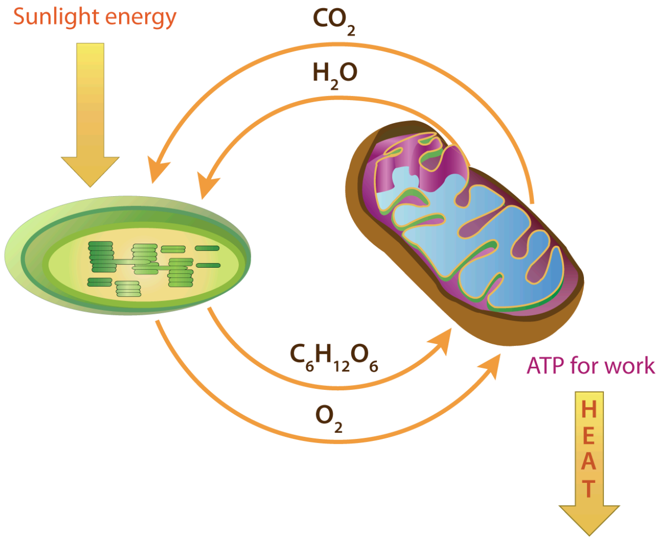
Yeasts (single-celled eukaryotic organisms) perform **alcoholic fermentation** in the absence of oxygen, making ethyl alcohol (drinking alcohol) and carbon dioxide. This process is used to make common food and drinks. For example, alcoholic fermentation is used to bake bread. The carbon dioxide bubbles allow the bread to rise, and the alcohol evaporates. In wine making, the sugars of grapes are fermented to produce the wine.

Animals and some bacteria and fungi carry out **lactic acid fermentation.** Lactic acid is a waste product of this process. Our muscles perform lactic acid fermentation during strenuous exercise, when oxygen cannot be delivered to the muscles quickly enough. The buildup of lactic acid is what makes your muscles sore after exercise.

Bacteria that produce lactic acid are used to make cheese and yogurt (**Figure** 3.16). Tooth decay is also increased by lactic acid from the bacteria that use the sugars in your mouth for energy.

Lesson Summary

- Cellular respiration is the breakdown of glucose to release energy in the form of ATP.
- If oxygen is not available, the process of fermentation can break down glucose without the presence of oxygen.



Photosynthesis	Cellular respiration
- It takes place in a chloroplast.	- It takes place in a mitochondrion.
- Carbon dioxide and water react, using light energy, to produce glucose and oxygen.	- Glucose and oxygen react to produce carbon dioxide, water, and energy (ATP).
- Light energy from the sun changes to chemical energy in glucose.	- Chemical energy in glucose changes to chemical energy in ATP.

Figure 3.15: Cellular respiration and photosynthesis are direct opposite reactions. Some of the ATP made in the mitochondria is used as energy for work, and some is lost to the environment as heat. Can you explain what is depicted in this diagram?

Figure 3.16: Products of fermentation include cheese (lactic acid fermentation) and wine (alcoholic fermentation).

A summary of cellular respiration can be viewed at http://www.youtube.com/watch?v=wqqYIgY40OE (8:50).

Figure 3.17: Cellular Respiration (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/597

Review Questions

Recall

1. What is the purpose of cellular respiration?
2. Where is glucose broken down to form ATP?

Apply Concepts

3. What are the products of alcoholic fermentation?
4. Write the chemical reaction for the overall process of cellular respiration.
5. What produces more ATP, aerobic or anaerobic cellular respiration? What is the purpose of fermentation?

Critical Thinking

6. Why do your muscles get sore after vigorous exercise?
7. Why is the cellular respiration equation the opposite of the photosynthesis equation?

Supplemental Links

- http://en.wikipedia.org/wiki/Cellular_respiration
- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookGlyc.html
- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.science.smith.edu/departments/Biology/Bio231/glycolysis.html

Points to Consider

- What do you think could happen if your cells divide uncontrollably?

- When new life is formed, do you think it receives all the DNA of the mother and the father?
- Why do you think you might need new cells throughout your life?

Image Sources

(1) CK-12 Foundation. http://commons.wikimedia.org/wiki/File:Animal_mitochondrion_diagram_en.svg. Public Domain.

(2) .

(3) http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg. Public Domain.

(4) Garrett and Kitty Wilkin. http://www.flickr.com/photos/gareandkitty/244555951/. CC-SA.

(5) http://commons.wikimedia.org/wiki/Image:Chloroplast-new.jpg. Public Domain.

(6) http://commons.wikimedia.org/wiki/File:Cell_membrane_detailed_diagram_en.svg. Public Domain.

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(9) http://en.wikipedia.org/wiki/Image:Osmotic_pressure_on_blood_cells_diagram.svg. Public Domain.

(10) http://commons.wikimedia.org/wiki/Image:Diffusion.en.jpg. Public Domain.

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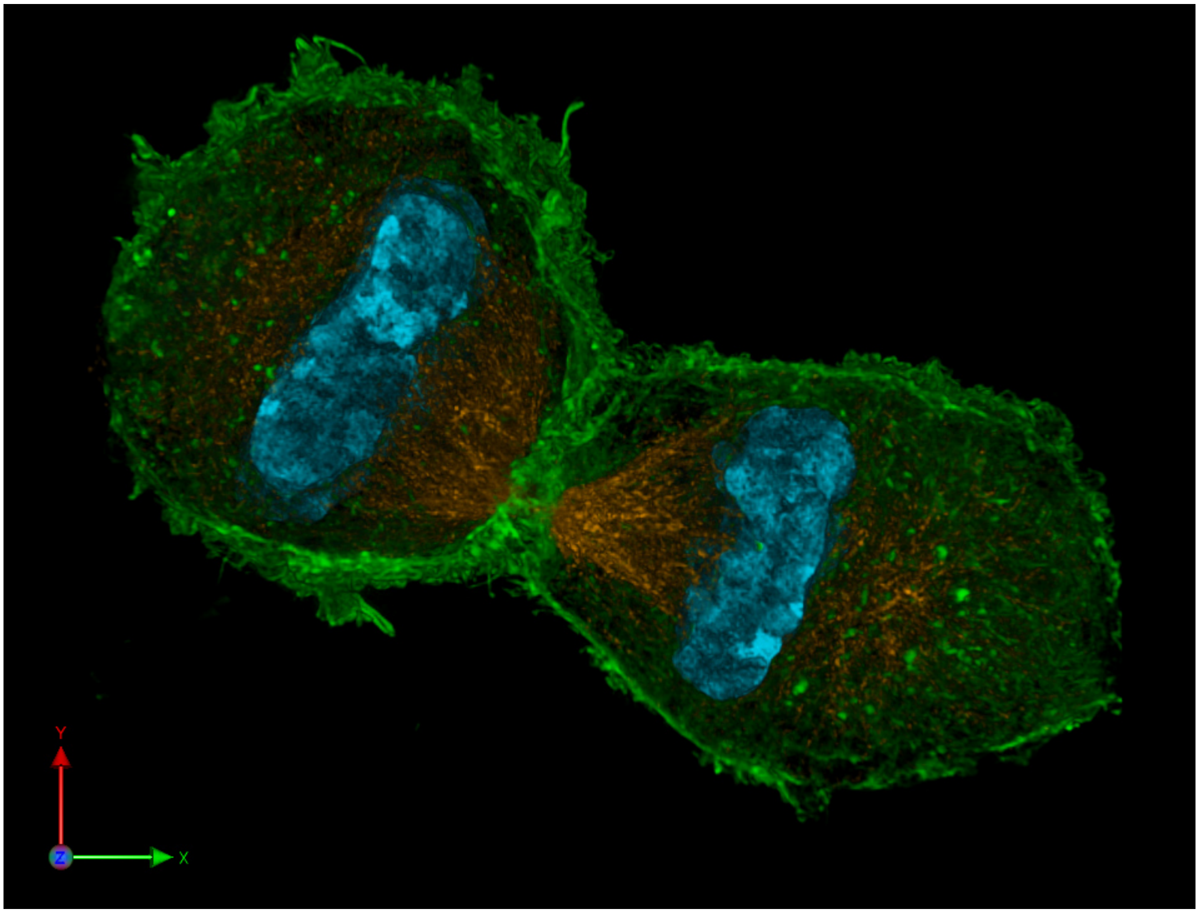
Chapter 4

MS Cell Division, Reproduction, and DNA



What has to happen for a cell to divide? Plenty. The above image shows the mitotic spindle in a sand dollar embryo. The mitotic spindle separates DNA in cells that are dividing. But that is just one step in the process. Why do you think cells need to divide? Do all cells divide the same way? How do cells help us reproduce? What would happen to living things if their cells failed to divide? What happens if cells divide uncontrollably? Think about these questions as you begin to understand why and how cells divide and how cell division helps the reproduction of all living things.

4.1 Cell Division

Lesson Objectives

- Explain why cells need to divide.
- List the stages of the cell cycle and explain what happens at each stage.
- List the stages of mitosis and explain what happens at each stage.

Check Your Understanding

- What is the cell theory?
- In what part of your cells is the genetic information located?

Vocabulary

anaphase cancer cell cycle
chromosome cytokinesis daughter cell
interphase metaphase mitosis
parent cell prophase sister chromatids
spindle telophase

Why Cells Divide

Imagine the first stages of life. In humans, a sperm fertilizes an egg, forming the first cell. But humans are made up of trillions of cells, so where do the new cells come from? Remember that according to cell theory, all cells must come from existing cells. From that one cell, an entire baby will develop.

How does a new life go from one cell to so many? The cell divides in half, creating two cells. Then those two cells divide, for a total of four cells. The new cells continue to divide and divide. One cell becomes two, then four, then eight, and so on (**Figure** 4.1).

Besides the development of a baby, there are many other reasons that cell division is necessary for life:

1. To grow and develop, you must form new cells. Imagine how often your cells must divide during a growth spurt. Growing just an inch requires countless cell divisions.
2. Cell division is also necessary to repair damaged cells. Imagine you cut your finger. After the scab forms, it will eventually disappear and new skin cells will grow to repair the wound. Where do these cells come from? Some of your existing skin cells divide and produce new cells.
3. Your cells can also simply wear out. Over time you must replace old and worn-out cells. Cell division is essential to this process.

The Cell Cycle

The process of cell division in eukaryotic cells is carefully controlled. The **cell cycle** is the lifecycle of a cell, with cell division at the end of the cycle. Like a human lifecycle that is made up of different phases,

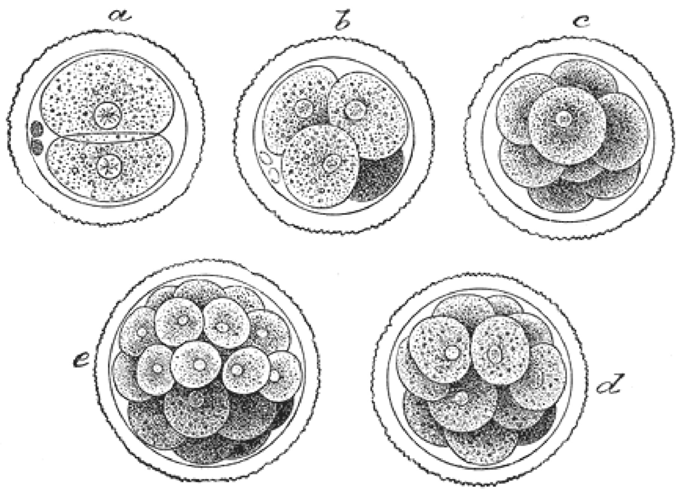


Figure 4.1: Cells divide repeatedly to produce an embryo. Previously the one-celled zygote (the first cell of a new organism) divided to make two cells (a). Each of the two cells divides to yield four cells (b), then the four cells divide to make eight cells (c), and so on. Through cell division, an entire embryo forms from one initial cell.

like childhood, adolescence, and adulthood, there are a series of steps that lead to cell division (**Figure** 4.2).

These steps can be divided into two main components, interphase and mitosis.

1. Interphase: The stage when the cell mostly performs its "everyday" functions. For example, it is when a kidney cell does what a kidney cell is supposed to do.
2. Mitosis: The stage when the cell prepares to become two cells.

Most of the cell cycle consists of **interphase,** the time between cell divisions. Interphase can be divided into three stages:

1. The first growth phase (G1): During the G1 stage, the cell doubles in size and doubles the number of organelles.
2. The synthesis phase (S): The DNA is replicated during this phase. In other words, an identical copy of all the cell's DNA is made. This ensures that each new cell has a set of genetic material identical to that of the parental cell. DNA replication will be further discussed in lesson 5.3.
3. The second growth phase (G2): Proteins are synthesized that will help the cell divide. At the end of interphase, the cell is ready to enter mitosis.

During **mitosis**, the nucleus divides. Mitosis is followed by **cytokinesis**, when the cytoplasm divides, resulting in two cells. After cytokinesis, cell division is complete. Scientists say that one **parent cell**, or the dividing cell, forms two genetically identical **daughter cells,** or the cells that divide from the parent cell. The term "genetically identical" means that each cell has an identical set of DNA, and this DNA is also identical to that of the parent cell. If the cell cycle is not carefully controlled, it can cause a disease called **cancer**, which causes cell division to happen too fast. A tumor can result from this kind of growth.

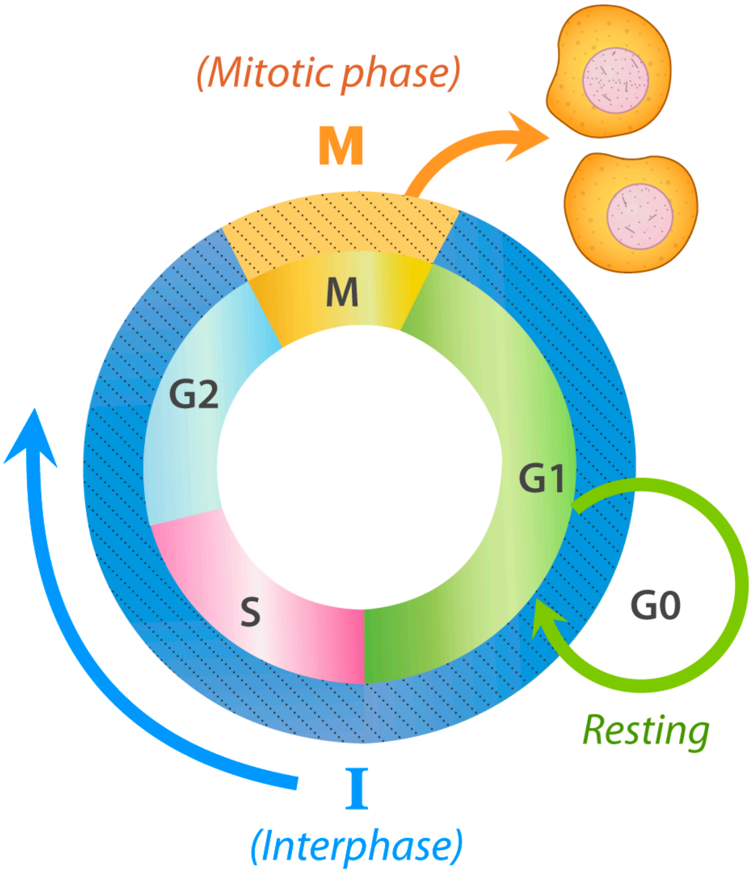


Figure 4.2: The cell cycle is the repeated process of growth and division. Notice that most of the cell cycle is spent in interphase (G1, S, and G2) (I). G0 is a resting state of the cell cycle.

Cancer is discussed in the video at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/11/RZhL7LDPk8w. (12:36).

Figure 4.3: Cancer (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/126

Two animations of the cell cycle are available at the following links. See if you can explain what is happening in these animations.

- http://www.wisc-online.com/objects/index_tj.asp?objID=AP13604
- http://www.cellsalive.com/cell_cycle.htm

Mitosis and Chromosomes

The genetic information of the cell, or DNA, is stored in the nucleus. During mitosis, two nuclei (plural for nucleus) must form, so that one nucleus can be in each of the new cells. The DNA inside of the nucleus is also copied. The copied DNA needs to be moved into the nucleus, so each cell can have a correct set of genetic instructions.

To begin mitosis, the DNA in the nucleus wraps around proteins to form **chromosomes**. Each organism has a unique number of chromosomes. In human cells, our DNA is divided up into 23 pairs of chromosomes. After the DNA is replicated during the S stage of interphase, each chromosome has two identical molecules of DNA, called **sister chromatids**, forming the "X" shaped molecule depicted in **Figure** 4.4.

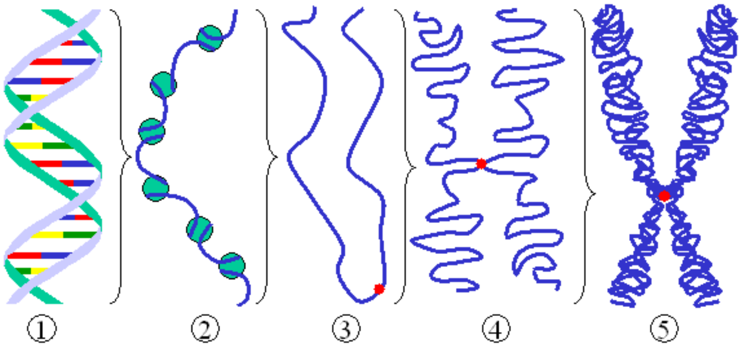


Figure 4.4: The DNA double helix wraps around proteins (2) and tightly coils a number of times to form a chromosome (5). This figure shows the complexity of the coiling process. The red dot shows the location of the centromere, where the microtubules attach during mitosis and meiosis.

The Four Phases of Mitosis

During mitosis, the two sister chromatids must be split apart. Each resulting chromosome is made of *1/2* of the "X". Through this process, each daughter cell receives one copy of each chromosome. Mitosis is divided into four phases (**Figure** 4.5):

1. **Prophase**: The chromosomes "condense," or become so tightly wound that you can see them under a microscope. The wall around the nucleus, called the nuclear envelope, disappears. **Spindles** also form and attach to chromosomes to help them move.
2. **Metaphase**: The chromosomes line up in the center of the cell. The chromosomes line up in a row, one on top of the next.
3. **Anaphase**: The two sister chromatids of each chromosome separate, resulting in two sets of identical chromosomes.
4. **Telophase**: The spindle dissolves and nuclear envelopes form around the chromosomes in both cells.

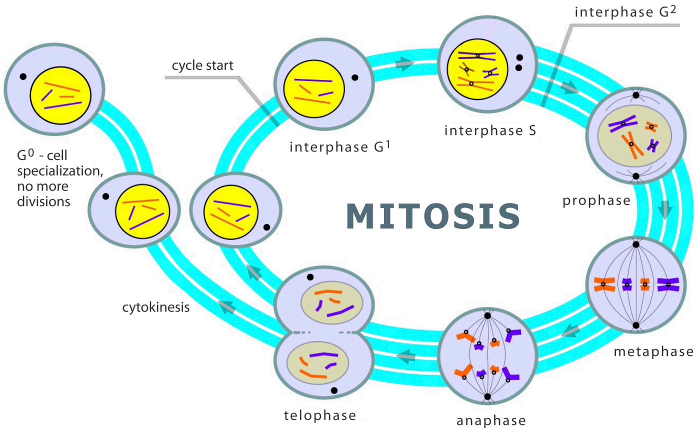


Figure 4.5: An overview of the cell cycle and mitosis: during prophase the chromosomes condense, during metaphase the chromosomes line up, during anaphase the sister chromatids are pulled to opposite sides of the cell, and during telophase the nuclear envelope forms.

Each new nucleus contains the exact same number and type of chromosomes as the original cell. The cell is now ready for cytokinesis, which literally means "cell movement." The cells separate, producing two genetically identical cells, each with its own nucleus. **Figure** 4.7 is a representation of dividing plant cells.

The phases of mitosis are discussed in the video: `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/8/LLKX_4DHE3I` (20:42).

Additional animations of mitosis can be viewed at the following links:

- `http://www.cellsalive.com/mitosis.htm`
- `http://www.youtube.com/watch?v=7hQ5xXJSmK4&#38;feature=related`

Figure 4.6: Phases of Mitosis (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/128

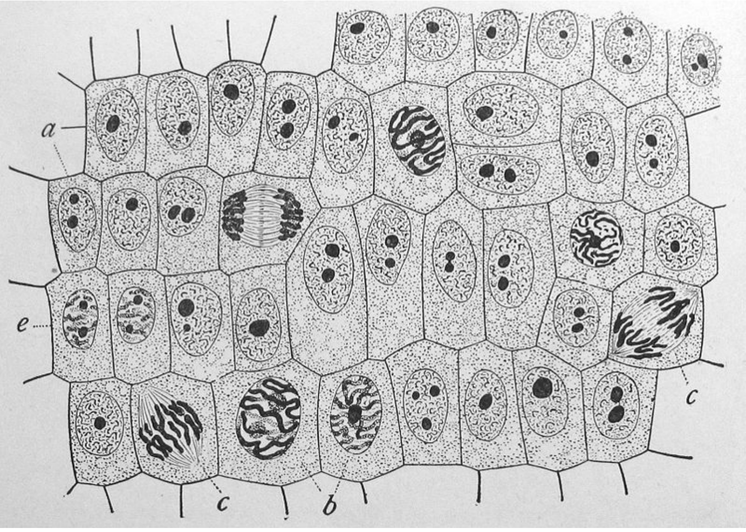


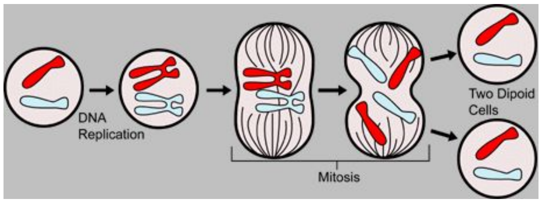
Figure 4.7: This is a representation of dividing plant cells. Cell division in plant cells differs slightly from animal cells as a cell wall must form. Note that most of the cells are in interphase. Can you find examples of the different stages of mitosis?

Mitosis in Real Time can be viewed at `http://www.youtube.com/watch?v=m73i1Zk8EA0&#38;feature=related` (0:19).

Figure 4.8: Mitosis in real time (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/598

Lesson Summary

- Cells divide for growth, development, reproduction and replacement of injured or worn-out cells.
- The cell cycle is a series of controlled steps by which a cell divides.
- During mitosis, the newly duplicated chromosomes are divided into two daughter nuclei.
- This summary diagram depicts one cell dividing into two genetically identical cells. Mitosis occurs after DNA replication. A diploid cell has two sets of chromosomes, as is shown here.



Review Questions

Recall

1. In what phase of mitosis are chromosomes moving toward opposite sides of the cell?
2. In what phase of mitosis do the duplicated chromosomes condense?
3. What step of the cell cycle is the longest?
4. What is the term for the division of the cytoplasm?
5. What happens during the S stage of interphase?

Apply Concepts

6. Interphase used to be considered the "resting" stage of the cell cycle. Why is this not correct?
7. What are some reasons that cells divide?
8. During what stage of the cell cycle does the cell double in size?

9. Why must cell division be tightly regulated?

Critical Thinking

10. What would happen if the cells in your liver stopped going through the process of mitosis?
11. What do you think might happen if mitosis could NOT stop happening to the cells in your brain?

Further Reading / Supplemental Links

- `http://en.wikipedia.org/wiki/Mitosis`
- `http://www.biology.arizona.edu/Cell_bio/tutorials/cell_cycle/cells3.html`
- `http://biology.clc.uc.edu/courses/bio104/mitosis.htm`
- `http://en.wikipedia.org/wiki/Cell_cycle`

Points to Consider

- How might a cell without a nucleus divide?
- How are new cells made that include the DNA of two parents?

4.2 Reproduction

Lesson Objectives

- Name the types of asexual reproduction.
- Explain the advantage of sexual reproduction.
- List the stages of meiosis and explain what happens in each stage.

Check Your Understanding

- Can something that does not reproduce still be considered living?
- What stores the genetic information that is passed on to offspring?
- How many chromosomes are in the human nucleus?

Vocabulary

allele asexual reproduction binary fission
crossing-over cross-pollination diploid
external fertilization gamete gonad
haploid internal fertilization meiosis
ovaries parthenogenesis sexual reproduction
testes zygote

What is reproduction?

What does reproduction mean? Can an organism be considered alive if it cannot make the next generation? Since individuals cannot live forever, they must reproduce for the species to survive. Reproduction is the ability to make the next generation.

Two methods of reproduction are:

1. **Asexual reproduction**, or the process of forming a new individual from a single parent.
2. **Sexual reproduction**, or the process of forming a new individual from two parents.

There are advantages and disadvantages to each method, but the result is always the same: a new life begins.

Asexual Reproduction

For humans to reproduce, DNA must be passed from the mother and father to the child. Humans cannot reproduce with just one parent, but it is possible in other organisms, like bacteria, some insects and some fish. These organisms can reproduce asexually, meaning that the offspring (children) have a single parent and share the exact same genetic material as the parent. This is very different from humans.

The advantage of asexual reproduction is that it can be very quick and does not require the meeting of a male and female organism. The disadvantage of asexual reproduction is that organisms cannot mix beneficial traits from both parents. An organism that is born through asexual reproduction only has the DNA from the one parent, and it is the exact copy of that parent. This can cause problems for the individual. For example, if the parent organism has a gene that causes cancer, the offspring will also have the gene that causes cancer. Organisms produced sexually may or may not inherit the cancerous gene because there are two parents mixing up their genes.

Types of organisms that reproduce asexually include:

1. Prokaryotic organisms, like bacteria. Bacteria reproduce through **binary fission,** where they grow and divide in half (**Figure** 4.9). First, their chromosome replicates (bacteria only have one chromosome) and the cell enlarges. After cell division, the two new cells each have one identical chromosome (mitosis is not necessary because bacteria do not have nuclei). Then, new membranes form to separate the two cells. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an animal species. Flatworms divide in two, then each half regenerates into a new flatworm identical to the original.
3. Different types of insects, fish, and lizards. These organisms can reproduce asexually through a process called parthenogenesis (**Figure** 4.10). **Parthenogenesis** happens when an unfertilized egg cell grows into a new organism. The resulting organism has half the amount of genetic material of the parent. Parthenogenesis is common in honeybees. In a hive, the sexually produced eggs become workers, while the asexually produced eggs become drones.

Sexual Reproduction

During sexual reproduction, two parents are involved. Most animals are dioecious, meaning there is a separate male and female sex, with the male producing sperm and the female producing eggs. When a sperm and egg meet, a **zygote,** the first cell of a new organism, is formed (**Figure** 4.11). The zygote will divide and grow into the embryo.

Let's explore how animals, plants, and fungi reproduce sexually:

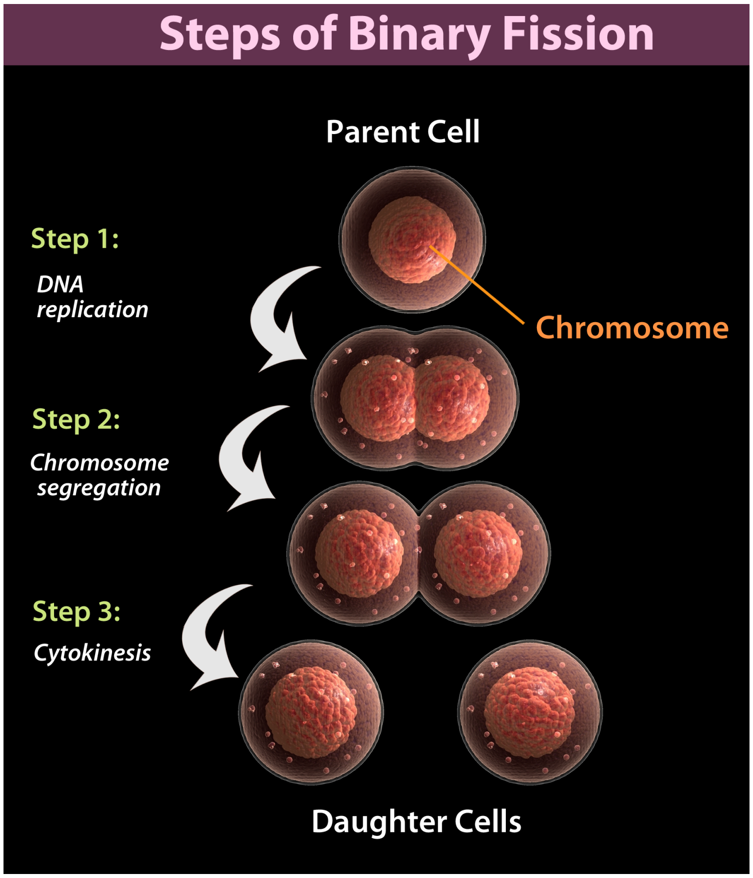


Figure 4.9: Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

Figure 4.10: This Komodo dragon was born by parthenogenesis.

Figure 4.11: During sexual reproduction, a sperm fertilizes an egg.

- Animals often have **gonads,** organs that produce eggs or sperm. The male gonads are the **testes,** which produce the sperm, and the female gonads are the **ovaries,** which produce the eggs. Sperm and egg, the two sex cells, are known as **gametes**, and can combine two different ways:

1. Fish and other aquatic animals release their gametes in the water, which is called **external fertilization.** These gametes will combine by chance. (**Figure** 4.12).
2. Animals that live on land reproduce by **internal fertilization**. Typically males have a penis that deposits sperm into the vagina of the female. Birds do not have penises, but they do have a chamber called the cloaca that they place close to another bird's cloaca to deposit sperm.

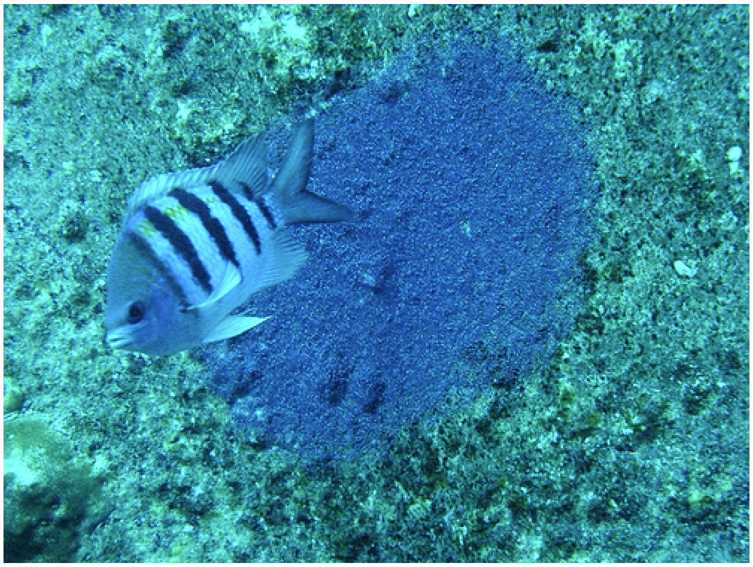


Figure 4.12: This fish guards her eggs, which will be fertilized externally.

- Plants can also reproduce sexually, but their reproductive organs are different from animals' gonads. Plants that have flowers have their reproductive parts in the flower. The sperm is contained in the pollen, while the egg is contained in the ovary, deep within the flower. The sperm can reach the egg two different ways:

1. In self-pollination, the egg is fertilized by the pollen of the same flower.

2. In **cross-pollination**, sperm from the pollen of one flower fertilizes the egg of another flower. Like other types of sexual reproduction, cross-pollination allows new combinations of traits. Cross-pollination occurs when pollen is carried by the wind to another flower. It can also occur when animal pollinators, like honeybees, or butterflies (**Figure** 4.13) carry the pollen from flower to flower.

- Fungi can also reproduce sexually, but instead of female and male sexes, they have (+) and (-) strains. When the filaments of a (+) and (-) fungi meet, the zygote is formed. Just like in plants and animals, each zygote receives DNA from two parent strains.

Figure 4.13: Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

Meiosis and Gametes

Meiosis is a process of cell division that produces sex cells, or gametes. Gametes are reproductive cells, such as sperm and egg. As gametes are produced, the number of chromosomes must be reduced by half. Why? The zygote must contain information from the mother and from the father, so the gametes must contain half of the chromosomes found in normal body cells.

In humans, our cells have 23 pairs of chromosomes, and each chromosome within a pair is called a **homologous chromosome.** For each of the 23 chromosome pairs, you received one chromosome from your father and one chromosome from your mother. The homologous chromosomes are separated when gametes are formed. Therefore, gametes have only 23 chromosomes, not 23 pairs.

Alleles are alternate forms of genes found on chromosomes. Since the separation of chromosomes into gametes is random, it results in different combinations of chromosomes (and alleles) in each gamete. With 23 pairs of chromosomes, there is a possibility of over 8 million different combinations of chromosomes in a gamete.

Haploid vs. Diploid

A cell with two sets of chromosomes is **diploid**, referred to as *2n,* where *n* is the number of sets of chromosomes. Most of the cells in a human body are diploid. A cell with one set of chromosomes, such as a gamete, is **haploid,** referred to as n. Sex cells are haploid. When a haploid sperm (n) and a haploid egg (n) combine, a diploid zygote will be formed ($2n$). In short, when a diploid zygote is formed, half of the DNA comes from each parent.

Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome.

Meiosis is divided into two divisions: Meiosis I and Meiosis II. Each division is similar to mitosis and can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Between the two divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

The phases of meiosis are discussed at `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/9/ijLc52LmFQg` (27:23).

Figure 4.14: Phases of Meiosis (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/130

Meiosis I

During meiosis I, the pairs of homologous chromosomes are separated from each other.

1. Prophase I: The homologous chromosomes line up together. During this time, a process that only happens in meiosis can occur. This process is called **crossing-over** (**Figure** 4.15), which is the exchange of DNA between homologous chromosomes. Crossing-over increases the new combinations of alleles in the gametes. Without crossing-over, the offspring would always inherit all of the many alleles on one of the homologous chromosomes. Also during prophase I, the spindle forms, the chromosomes condense as they coil up tightly, and the nuclear envelope disappears.
2. Metaphase I: The homologous chromosomes line up in pairs in the middle of the cell. Chromosomes from the mother or from the father can each attach to either side of the spindle. Their attachment is random, so all of the chromosomes from the mother or father do not end up in the same gamete. The gamete will contain some chromosomes from the mother and some chromosomes from the father.
3. Anaphase I: The homologous chromosomes separate.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because the nucleus will divide again. No DNA replication happens between meiosis I and meiosis II because the chromosomes are already duplicated.

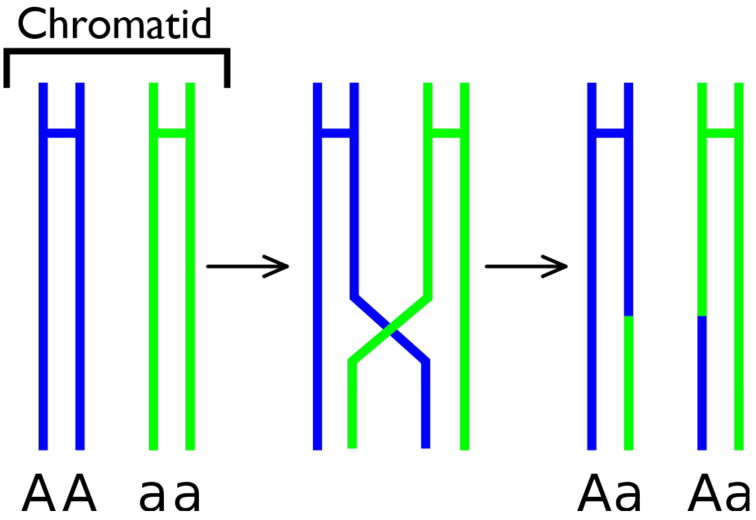


Figure 4.15: During crossing-over, segments of DNA are exchanged between sister chromatids. Notice how this can result in an allele (A) on one sister chromatid being moved onto the other sister chromatid.

Meiosis II

During meiosis II, the sister chromatids are separated and the gametes are generated.

The steps are outlined below:

1. Prophase II: The chromosomes condense.
2. Metaphase II: The chromosomes line up one on top of the next along the middle of the cell.
3. Anaphase II: The sister chromatids separate.
4. Telophase II: Nuclear envelopes form around the chromosomes in all four cells.

After cytokinesis, each cell has divided again. Therefore, meiosis results in four daughter cells with half the DNA of the parent cell (**Figure** 4.16). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

Mitosis vs. Meiosis: A Comparison

Mitosis, meiosis and sexual reproduction are discussed at `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/7/kaSIjIzAtYA` (18:23).

Figure 4.18 is a comparison between binary fission, mitosis, and meiosis. Mitosis and meiosis are also compared in **Table** 4.1.

Animations of meiosis can be found at the following sites:

- `http://www.cellsalive.com/meiosis.htm`
- `http://www.youtube.com/watch?v=MqaJqLL49a0&#38;NR=1`
- `http://www.youtube.com/watch?v=uh7c8YbYGqo&#38;feature=related`

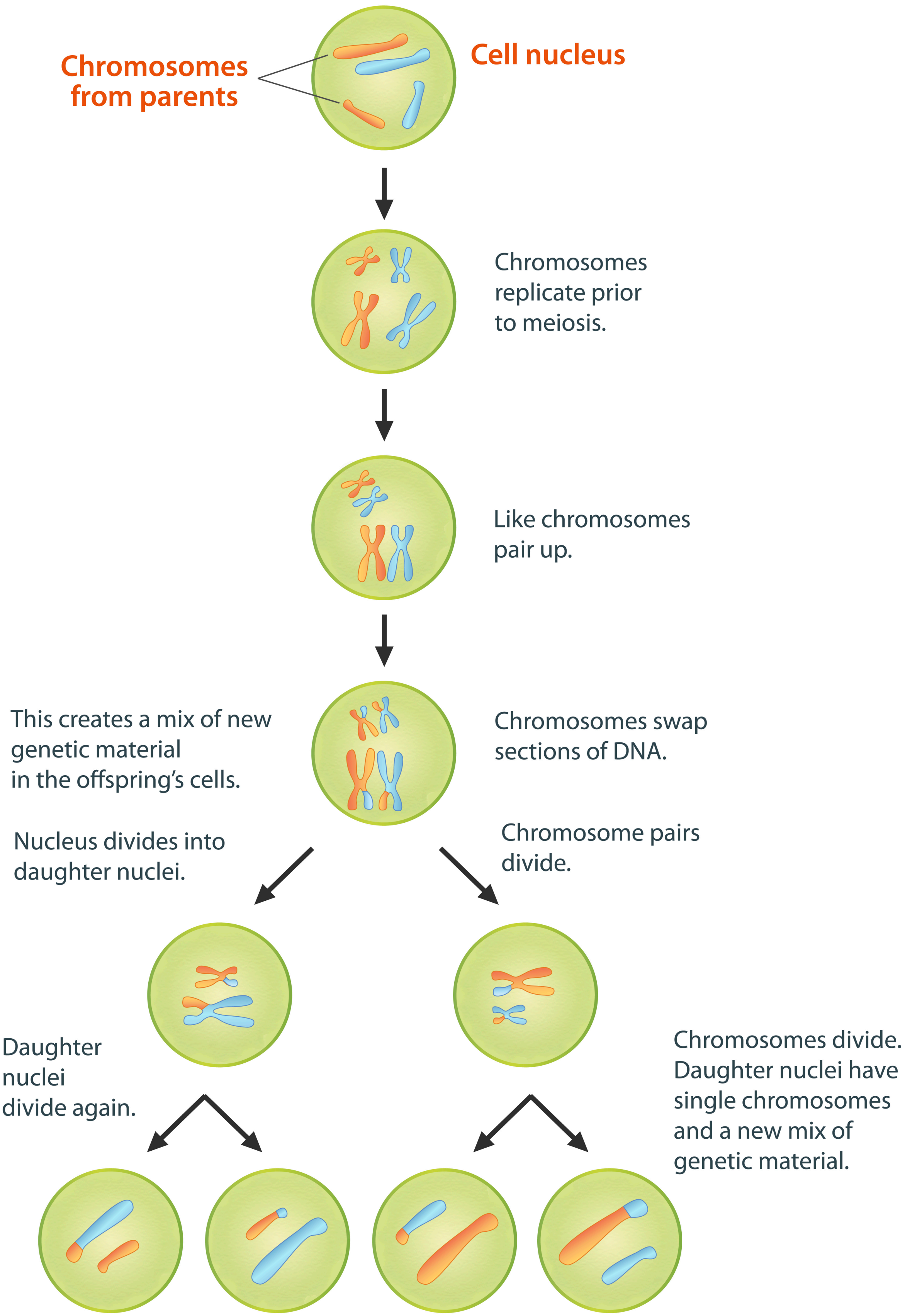

Chromosomes from parents
Cell nucleus
Chromosomes replicate prior to meiosis.
Like chromosomes pair up.
This creates a mix of new genetic material in the offspring's cells.
Chromosomes swap sections of DNA.
Nucleus divides into daughter nuclei.
Chromosome pairs divide.
Daughter nuclei divide again.
Chromosomes divide. Daughter nuclei have single chromosomes and a new mix of genetic material.

Figure 4.16: An overview of meiosis.

Figure 4.17: Mitosis, Meiosis and Sexual Reproduction (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/129

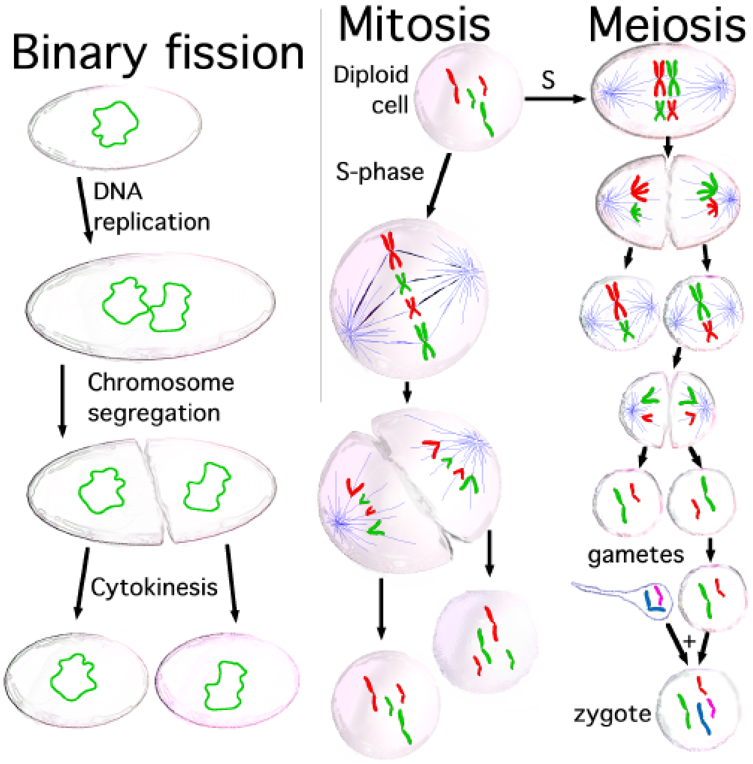


Figure 4.18: A comparison between binary fission, mitosis, and meiosis.

Table 4.1: **Mitosis vs. Meiosis: A Comparison**

	Mitosis	**Meiosis**
Purpose:	To produce new cells	To produce gametes
Number of cells produced:	2	4
Rounds of Cell Division:	1	2
Haploid or Diploid:	Diploid	Haploid
Daughter cells identical to parent cells?	Yes	No
Daughter cells identical to each other?	Yes	No

Lesson Summary

- Organisms can reproduce sexually or asexually.
- The gametes in sexual reproduction must have half the DNA of the parent.
- Meiosis is the process of nuclear division that forms gametes.

Review Questions

Recall

1. What is parthogenesis?
2. During what phase of meiosis do homologous chromosomes separate?
3. What is the purpose of meiosis?
4. In what phase of meiosis do homologous chromosomes pair up?

Apply Concepts

5. Explain how organisms reproduce asexually.
6. Explain how birds fertilize their eggs.
7. How do most plants reproduce sexually?
8. Compare and contrast the process of mitosis and the process of meiosis.

Critical Thinking

9. How would sexual reproduction in a lizard be different than in a fish?
10. What is the advantage of sexual reproduction over asexual reproduction?
11. If an organism has 12 chromosomes in its cells, how many chromosomes will be in its gametes?

Further Reading / Supplemental Links

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookmeiosis.html

- http://www.biology.arizona.edu/Cell_BIO/tutorials/meiosis/page3.html
- http://en.wikipedia.org/

Points to Consider

- What must be replicated prior to mitosis?
- How do you think DNA might be replicated?
- What might happen if there is a mistake during DNA replication?

4.3 DNA, RNA, and Protein Synthesis

Lesson Objectives

- Explain the chemical composition of DNA.
- Explain how DNA synthesis works.
- Explain how proteins are coded for and synthesized.
- Describe the three types of RNA and the functions of each.

Check Your Understanding

- What is the purpose of DNA?
- When is DNA replicated?

Vocabulary

amino acid DNA DNA replication
double helix gene mutagen
mutation nucleotide RNA
semiconservative replication transcription translation

What is DNA?

DNA, is the material that makes up our chromosomes and stores our genetic information. When you build a house, you need a blueprint, a set of instructions that tells you how to build. The DNA is like the blueprint for living organisms. The genetic information is a set of instructions that tell your cells what to do.

DNA is an abbreviation for deoxyribonucleic acid. As you may recall, nucleic acids are a type of macromolecule that store information. The *deoxyribo* part of the name refers to the name of the sugar that is contained in DNA, deoxyribose. DNA may provide the instructions to make up all living things, but it is actually a very simple molecule. DNA is made of a long chain of nucleotides.

Nucleotides are composed of 3 main parts:

1. Phosphate group

2. 5-carbon sugar
3. Nitrogen-containing base

The only difference between each nucleotide is the identity of the base. There are only four possible bases that make up each DNA nucleotide: adenine (A), guanine (G), thymine (T), and cytosine (C).

The various sequences of these four bases make up the genetic code of your cells. It may seem strange that there are only four letters in the "alphabet" of DNA. But since your chromosomes contain millions of nucleotides, there are many, many different combinations possible with those four letters.

But how do all these pieces fit together? James Watson and Francis Crick won the Nobel Prize in 1962 for piecing together the structure of DNA. Together with the work of Rosalind Franklin and Maurice Wilkins, they determined that DNA is made of two strands of nucleotides formed into a **double helix**, or a two-stranded spiral, with the sugar and phosphate groups on the outside, and the paired bases connecting the two strands on the inside of the helix (**Figure** 4.19 and **Figure** 4.20).

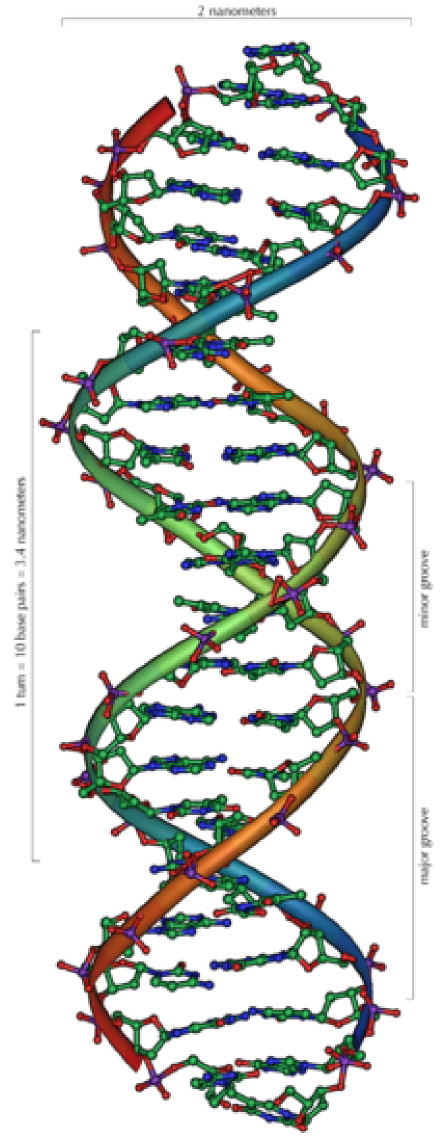


Figure 4.19: DNA's three-dimensional structure is a double helix. The hydrogen bonds between the bases at the center of the helix hold the helix together.

Base-Pairing

The bases in DNA do not pair randomly. When Erwin Chargaff looked closely at the bases in DNA, he noticed that the percentage of adenine (A) in the DNA always equaled the percentage of thymine (T), and the percentage of guanine (G) always equaled the percentage of cytosine (C). Watson and Crick's model explained this result by suggesting that A always pairs with T and G always pairs with C in the DNA helix. Therefore A and T, and G and C, are "complementary bases," or bases that always pair together. For example, if one DNA strand reads ATGCCAGT, the other strand will be made up of the complementary bases: TACGGTCA.

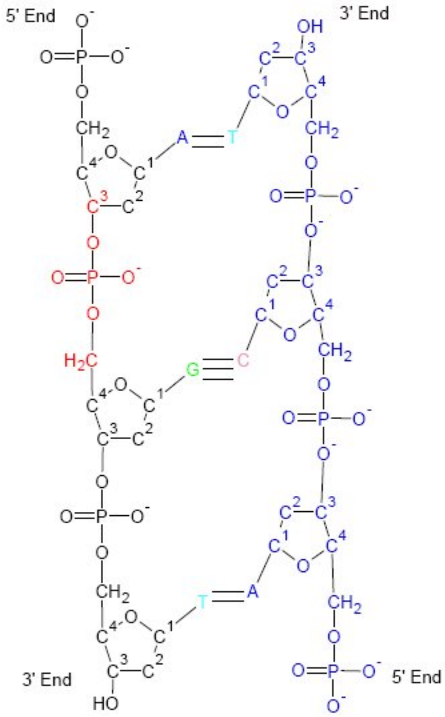


Figure 4.20: The chemical structure of DNA includes a chain of nucleotides consisting of a 5-carbon sugar, a phosphate group, and a nitrogen base. Notice how the sugar and phosphate form the backbone of DNA (one strand in blue), with the hydrogen bonds between the bases joining the two strands.

The vocabulary of DNA, including chromosomes, chromatids, chromatin, transcription, translation, and replication, is discussed at `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/6/s9HPNwXd9fk` (18:23).

DNA Replication

The base pairing rules are crucial for the process of replication. **DNA replication** occurs when DNA is copied to form an identical molecule of DNA. DNA replication happens before cell division. Below are the steps involved in DNA replication:

1. The DNA helix unwinds like a zipper, as the bonds between the base pairs are broken.

Figure 4.21: Chromosomes, Chromatids, Chromatin, etc. (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/127

2. The two single strands of DNA then each serve as a template for a new stand to be created. Using DNA as a template means that the bases are placed in the right order because of the base pairing rules. If ATG is on the "template strand," then TAC will be on the new DNA strand.
3. The new set of nucleotides then join together to form a new strand of DNA. The process results in two DNA molecules, each with one old strand and one new strand of DNA.

This process is known as **semiconservative replication** because one strand is conserved (kept the same) in each new DNA molecule (**Figure** 4.22).

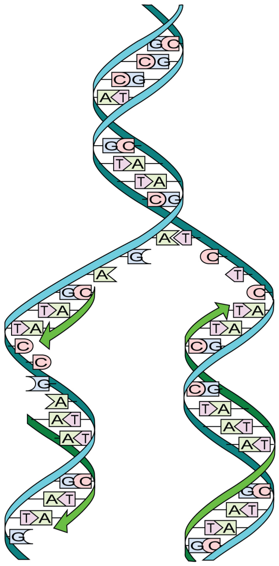


Figure 4.22: DNA replication occurs when the DNA strands "unzip", and the original strands of DNA serve as a template for new nucleotides to join and form a new strand.

Protein Synthesis

The DNA sequence contains the instructions to make units called amino acids, which are assembled in a specific order to make proteins. In short, DNA contains the instructions to create proteins. Each strand of DNA has many separate sequences that code for a specific protein. Units of DNA that contain code for the creation of one protein are called **genes.** An overview of protein synthesis can be seen at this animation: `http://www.biostudio.com/demo_freeman_protein_synthesis.htm`

Cells Can Turn Genes On or Off

There are about 22,000 genes in every human cell. Does every human cell have the same genes? Yes. Does every human cell use the same genes to make the same proteins? No. In a multicellular organism, such as us, cells have specific functions because they have different proteins. They have different proteins because different genes are expressed in different cell types.

Imagine that all of your genes are ”turned off.” Each cell type only ”turns on” (or expresses) the genes that have the code for the proteins it needs to use. So different cell types ”turn on” different genes, allowing different proteins to be made, giving different cell types different functions.

Three Types of RNA

DNA contains the instructions to create proteins, but it does not make proteins itself. DNA is located in the nucleus, while proteins are made on ribosomes in the cytoplasm. So DNA needs a messenger to bring its instructions to a ribosome located outside of the nucleus. DNA sends out a message, in the form of **RNA** (ribonucleic acid), describing how to make the protein.

There are three types of RNA directly involved in protein synthesis:

- Messenger RNA (mRNA) carries the instructions from the nucleus to the cytoplasm.
- The other two forms of RNA, ribosomal RNA (rRNA) and transfer RNA (tRNA) are involved in the process of ordering the amino acids to make the protein.

All three RNAs are nucleic acids, made of nucleotides, similar to DNA. The RNA nucleotide is different from the DNA nucleotide in the following ways:

- RNA contains a different kind of sugar, called ribose.
- In RNA, the base uracil (U) replaces the thymine (T) found in DNA.
- RNA is a single strand.

DNA Transcription

mRNA is created by using DNA as a template. The process of constructing an mRNA molecule from DNA is known as **transcription** (**Figure** 4.24 and **Figure** 4.25). The double helix of DNA unwinds and the nucleotides follow basically the same base pairing rules to form the correct sequence in the mRNA. This time, however, U pairs with each A in the DNA. In this manner, the genetic code is passed on to the mRNA.

Two multimedia links of protein synthesis are provided below.

- `http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a2.html`

Transcription and Translation can be viewed at `http://www.youtube.com/watch?v=41_Ne5mS2ls` (4:06).

Figure 4.23: Transcription and Translation (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/599

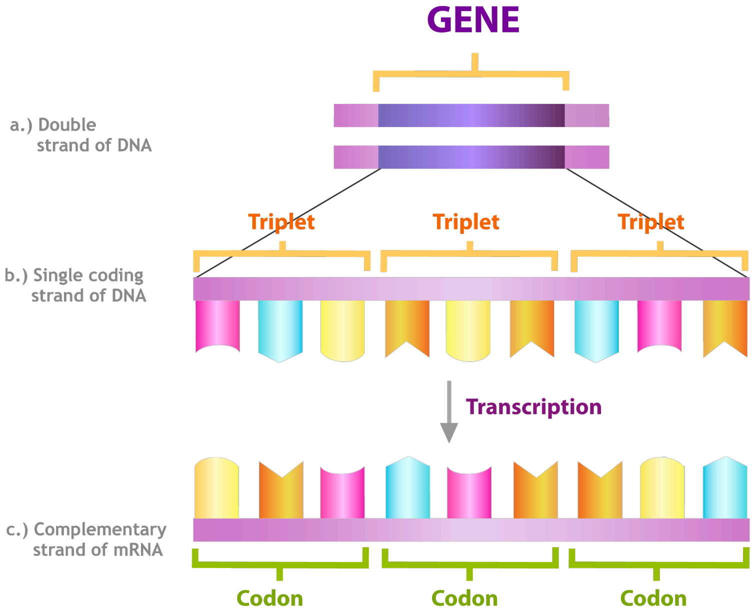


Figure 4.24: Each gene (a) contains triplets of bases (b) that are transcribed into RNA (c). Every triplet, or codon, encodes for a unique amino acid.

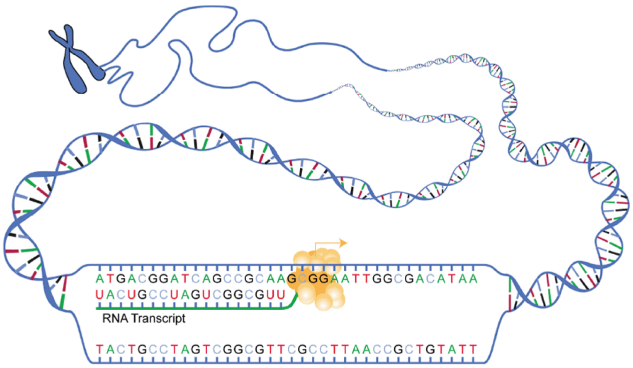

ATGACGGATCAGCCGCAAGCGGAATTGGCGACATAA
UACUGCCUAGUCGGCGUU
RNA Transcript
TACTGCCTAGTCGGCGTTCGCCTTAACCGCTGTATT

Figure 4.25: Base-pairing ensures the accuracy of transcription. Notice how the helix must unwind for transcription to take place.

RNA Translation

The mRNA is directly involved in the protein-making process. mRNA tells the ribosome (**Figure** 4.26) how to create a protein. The process of reading the mRNA code in the ribosome to make a protein is called **translation** (**Figure** 4.27). Sets of three bases, called codons, are read in the ribosome, the organelle responsible for making proteins.

The following are the steps involved in translation:

1. mRNA travels to the ribosome from the nucleus.
2. The base code in the mRNA determines the order of the amino acids in the protein. The genetic code in mRNA is read in "words" of three letters (triplets), called **codons.** There are 20 amino acids and different codons code for different ones. For example, GGU codes for the amino acid glycine, while GUC codes for valine.
3. tRNA reads the mRNA code and brings a specific amino acid to attach to the growing chain of amino acids. Each tRNA carries only one type of amino acid and only recognizes one specific codon.
4. tRNA is released from the amino acid.
5. Three codons, UGA, UAA, and UAG, indicate that the protein should stop adding amino acids. They are called "stop codons" and do not code for an amino acid. Once tRNA comes to a stop codon, the protein is set free from the ribosome.

The chart in **Figure** 4.28 is used to determine which amino acids correspond to which codons. An interactive activity for transcribing and translating a gene can be found at `http://learn.genetics.utah.edu/units/basics/transcribe/`.

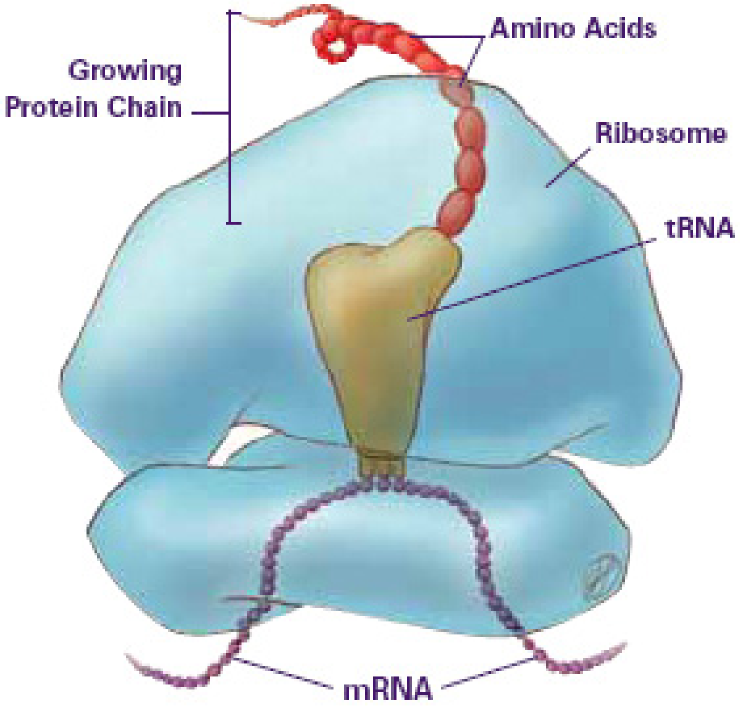


Figure 4.26: Ribosomes translate RNA into a protein with a specific amino acid sequence. The tRNA binds and brings to the ribosome the amino acid encoded by the mRNA. Ribosomes are made of rRNA and proteins.

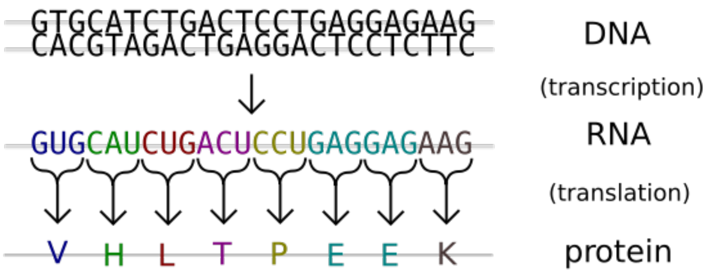


Figure 4.27: This summary of how genes are expressed shows that DNA is transcribed into RNA, which is translated in turn to protein.

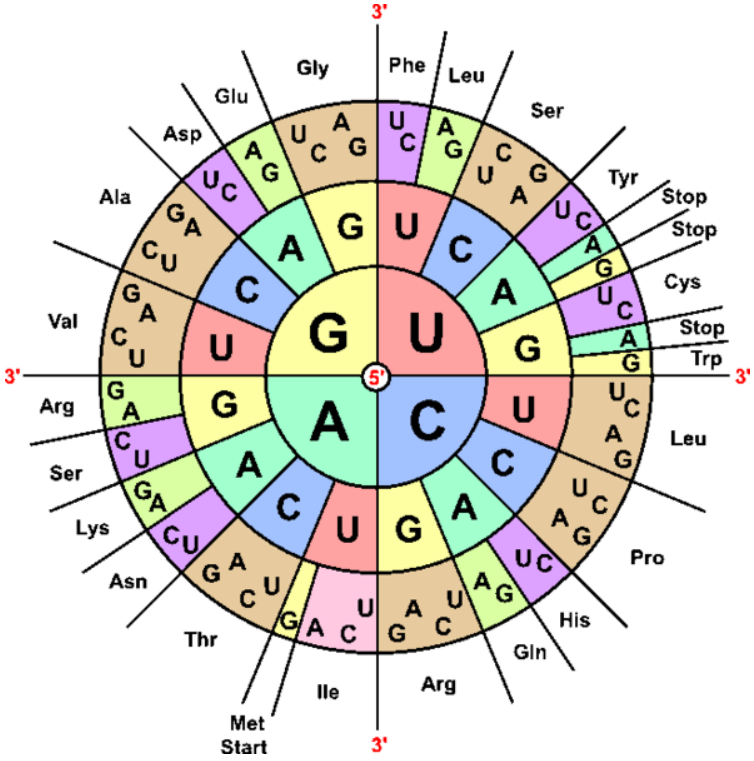


Figure 4.28: This chart shows the genetic code used by all organisms. For example, an RNA codon reading GUU would encode for a valine (Val) according to this chart. Start at the center for the first base of the three base codon, and work your way out. Notice for valine, the second base is a U and the third base of the codon may be either a G, C, A, or U. Similarly, glycine (Gly) is encoded by a GGG, GGA, GGC, and GGU.

Mutations

The process of DNA replication is not always 100% accurate, and sometimes the wrong base is inserted in the new strand of DNA. A permanent change in the sequence of DNA is known as a **mutation**. Small changes in the DNA sequence are usually point mutations, which is a change in a single nucleotide. A mutation may have no effect. Sometimes, a mutation can cause the protein to be made incorrectly, which can affect how well the protein works, or whether it works at all. Usually the loss of a protein function is detrimental to the organism.

However, in rare circumstances, the mutation can be beneficial. For example, suppose a mutation in an animal's DNA causes the loss of an enzyme that makes a dark pigment in the animal's skin. If the population of animals has moved to a light colored environment, the animals with the mutant gene would have a lighter skin color and be better camouflaged. So in this case, the mutation is beneficial.

Mutations may also occur in chromosomes. Possible types of mutations in chromosomes (**Figure** 4.29) include:

1. Deletion: When a segment of DNA is lost, so there is a missing segment in the chromosome.
2. Duplication: When a segment of DNA is repeated, creating a longer chromosome.
3. Inversion: When a segment of DNA is flipped and then reattached to the chromosome.
4. Insertion: When a segment of DNA from one chromosome is added to another, unrelated chromosome.
5. Translocation: When two segments from different chromosomes change positions.

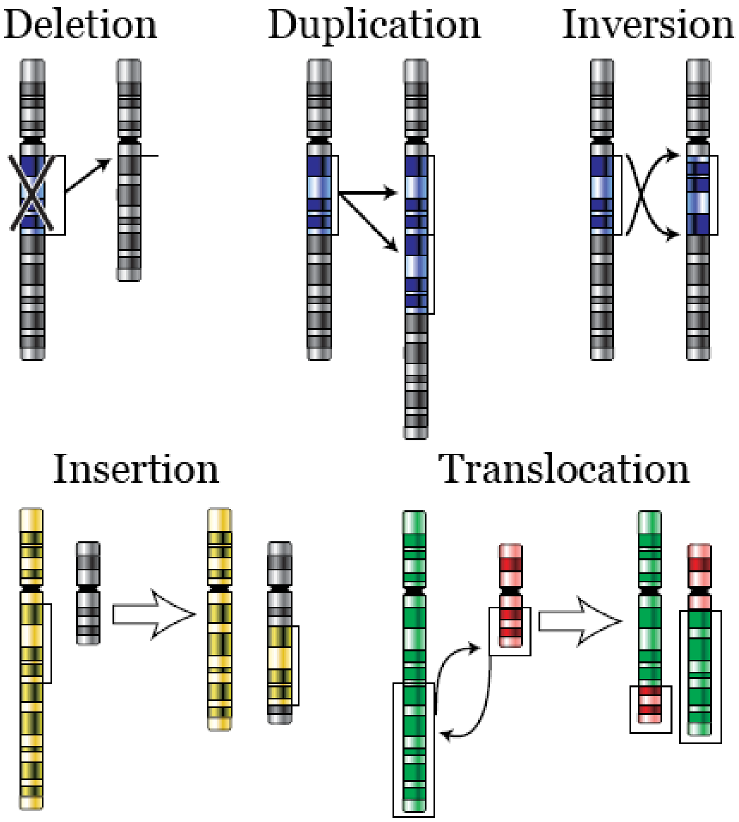


Figure 4.29: Mutations can arise in DNA through deletion, duplication, inversion, insertion, and translocation within the chromosome.

If a single base is deleted (called a point mutation), there can be huge effects on the organism because this may cause a ”frameshift mutation.” Remember that the bases are read in groups of three by the tRNA. If the reading frame gets off by one base, the resulting sequence will consist of an entirely different set of codons. The reading of an mRNA is like reading three letter words of a sentence. Imagine you wrote “the big dog ate the red cat”. If you take out the second letter from ”big”, the frame will be shifted so now it will read “ the bgd oga tet her edc at.” One single deletion makes the whole “sentence” impossible to read.

Many mutations are not caused by errors in replication. Mutations can happen spontaneously and they can be caused by **mutagens** in the environment. Some chemicals, such as those found in tobacco smoke, can be mutagens. Sometimes mutagens can also cause cancer. Tobacco smoke, for example, is often linked to lung cancer.

Lesson Summary

- DNA stores the genetic information of the cell in the sequence of its 4 bases: adenine, thymine, guanine, and cytosine.
- The information in a small segment of DNA, a gene, is sent by mRNA to the ribosome to synthesize a protein.
- Within the ribosome, tRNA reads the mRNA in sets of three bases (triplets), called codons, which encode for the specific amino acids that make up the protein.
- A mutation is a permanent change in the sequence of bases in DNA.

Review Questions

Recall

1. What is a nucleotide made out of?

2. Describe the process of DNA replication.

3. What is made in the process of transcription?

4. What is made in the process of translation?

5. Name a mutagen.

Apply Concepts

6. Translate the following segment of DNA into RNA: AGTTC

7. Write the complimentary DNA nucleotides to this strand of DNA: GGTCCA

8. Nucleotides are subunits of which two macromolecules?

9. Amino acids are subunits that make up what macromolecule?

10. How does RNA encode for proteins?

Critical Thinking

11. How does a mutation in a strand of DNA affect translation and transcription?

12. Given the DNA sequence, ATGTTAGCCTTA, what is the mRNA sequence? What is the amino acid sequence?

Further Reading / Supplemental Links

- http://nobelprize.org/educational_games/medicine/dna_double_helix/readmore.html
- http://learn.genetics.utah.edu/units/basics/builddna/
- http://enwikipedia.org/
- http://sickle.bwh.harvard.edu/scd_background.html

Points to Consider

- Your cells have "proofreaders" that replace mismatched pairs that occurred during DNA synthesis. How would that affect the rate of mutation in your body?
- There are many diseases due to mutations in the DNA. These are known as genetic diseases, and many can be passed onto the next generation. Think about how a single base change cause a huge medical problem.
- Your DNA contains the instructions to make you. So is everyone's DNA different? Can it be used to distinguish individuals, like a fingerprint?

Image Sources

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Chapter 5

MS Skin, Bones, and Muscles

What are human skeletons made out of? Bone. What is connected to the bone? Muscle. What layer rests on top of muscle to protect your body? Skin. Bones, muscle, and skin form the foundation of your body.

The person in the above figure is moving. How do his bones help him to move? How are his muscles working with his bones? What would happen if the he did not have skin? What would happen if his bones were removed? Human bodies cannot work without a collection of different tissues and organs. If you remove one, the others will not operate in the same way.

While reading this chapter, think about the individual functions of bones, muscles, and skin. But also remember to consider how they work together to form a whole human.

5.1 Organization of Your Body

Lesson Objectives

- List the levels of organization in the human body.
- Identify the four types of tissues that make up the body.
- Identify 12 organ systems.
- Describe how organs and organ systems work together to maintain homeostasis.

Check Your Understanding

- What is a cell?
- What are some of the differences between a prokaryotic cell and an eukaryotic cell?
- What are some of the basic functions of animal cells?

Vocabulary

cardiovascular system connective tissue epithelial tissue
feedback regulation muscular tissue negative feedback loop
nervous tissue positive feedback loop

An introduction to the human body can be viewed at http://www.youtube.com/watch?v=AOqTYNuMX78 (1:45).

Figure 5.1: The Human Body (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/613

Cells, Tissues, Organs

Homeostasis

The men in **Figure** 5.2 just jumped into freezing icy water. They are having fun, but imagine how cold they must feel! What happens to their bodies when one moment they are warm and the next they are freezing? If their bodies are working right, they will begin to shiver. Shivering helps the body return to a stable temperature.

The ability of the body to maintain a stable internal environment in response to change is called homeostasis. Homeostasis allows your body to adapt to change. Change might be from jumping into cold water or running in hot weather. Or it might be from not getting enough food when you are hungry. Homeostasis is a very important characteristic of living things.

Figure 5.2: The bodies of these swimmers are working hard to maintain homeostasis while they are in the icy pool water. Otherwise, their life processes would stop working as soon as they got into the water.

Homeostasis and Cells

Cells are the most basic units of life in your body. They must do many jobs to maintain homeostasis, but each cell does not have to do every job. Cells have specific jobs to maintain homeostasis. For example, nerve cells move electrical messages around the body, and white blood cells patrol the body and attack invading bacteria.

There are many additional different types of cells. Other cells include red blood cells, skin cells, cells that line the inside of your stomach, and muscle cells.

Groups of Cells Form Tissues

Cells are grouped together to carry out specific functions. A group of cells that work together is called a tissue. Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is shown in **Figure** 5.3.

1. **Epithelial tissue** is made up of layers of tightly packed cells that line the surfaces of the body. Examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.
2. **Connective tissue** is made up of many different types of cells that are all involved in structure and support of the body. Examples include tendon, cartilage, and bone. Blood is also classified as a specialized connective tissue.
3. **Muscle tissue** is made up of bands of cells that contract and allow bodies to move. There are three types of muscle tissue: smooth muscle, skeletal muscle, and cardiac muscle.
4. **Nervous tissue** is made up of the nerve cells that together form the nervous system. Nervous tissue is found in nerves, the spinal cord, and the brain.

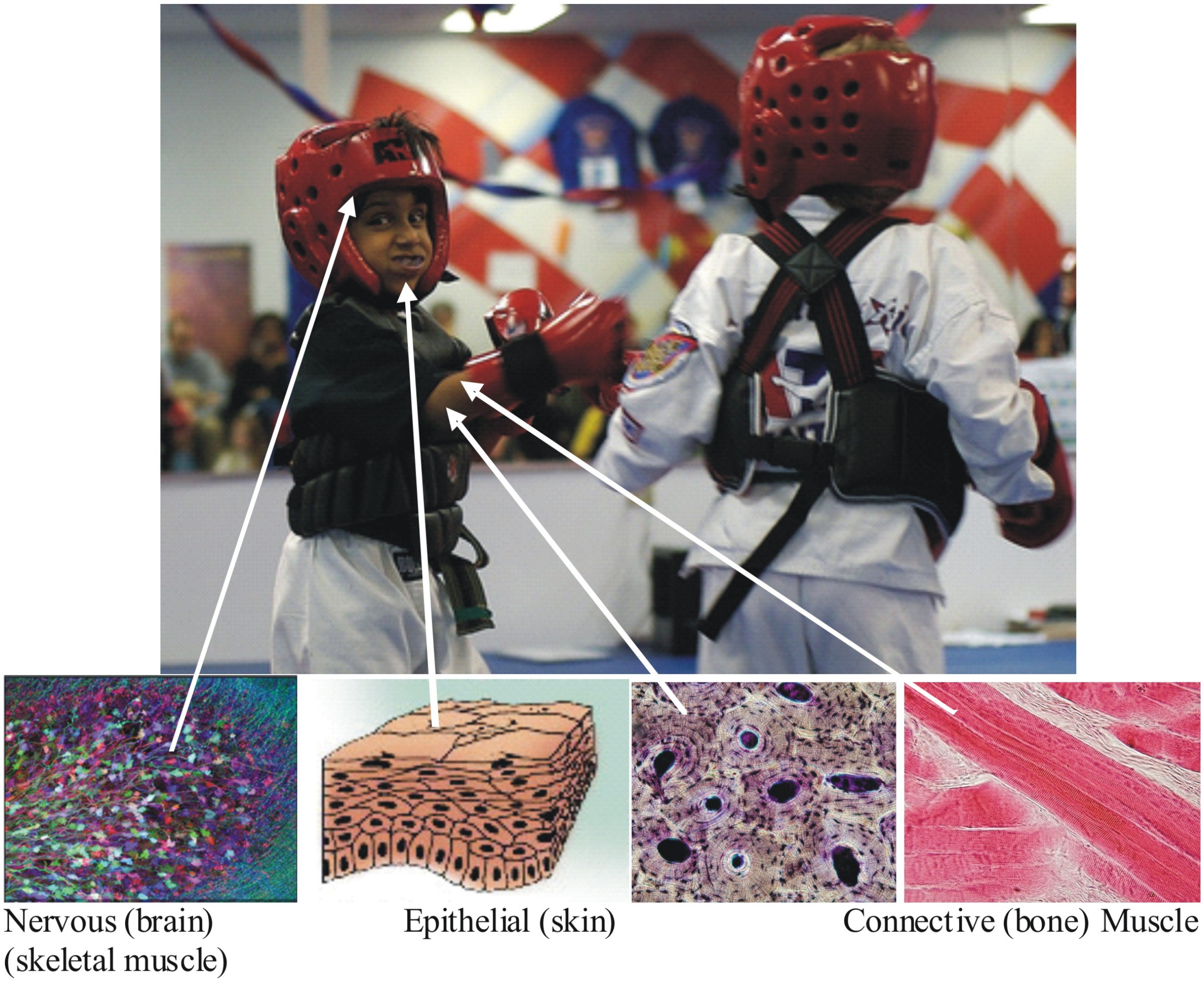


Figure 5.3: Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

Groups of Tissues Form Organs

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An organ is a structure made of two or more tissues that work together. The heart, shown in **Figure** 5.4, is made up of the four types of tissues.

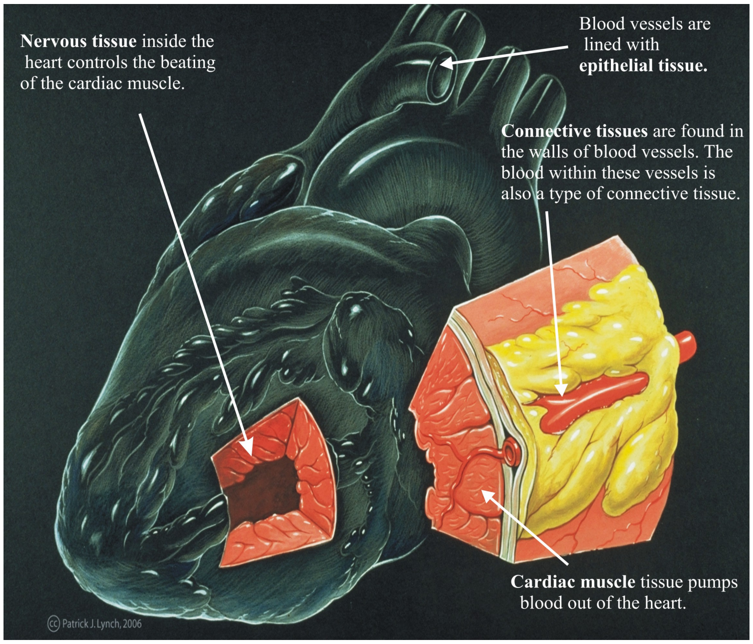

Nervous tissue inside the heart controls the beating of the cardiac muscle.
Blood vessels are lined with **epithelial tissue.**
Connective tissues are found in the walls of blood vessels. The blood within these vessels is also a type of connective tissue.
Cardiac muscle tissue pumps blood out of the heart.
Patrick J. Lynch, 2006

Figure 5.4: The four different tissue types work together in the heart as they do in the other organs.

Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together form an organ system. Together, your heart, blood, and blood vessels form your **cardiovascular system**.

What other organ systems can you think of?

Organ Systems Work Together

Your body's 12 organ systems are shown in **Table** 5.1. Your organ systems do not work alone in your body. They must all be able to work together to maintain homeostasis.

For example, when the men in **Figure** 5.2 jumped into the cold water, their integumentary system (skin), cardiovascular system, muscular system, and nervous system worked quickly together to ensure the icy water did not cause harm to their bodies.

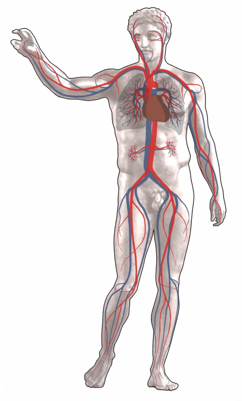
For example, the nervous system sent nerve messages from the skin to tell the cardiovascular system to reduce the blood flow to the skin. Blood flow is then increased to the internal organs and large muscles to help keep them warm and supply them with oxygen. The nervous system also sent messages to the respiratory system to breathe faster. This allows for more oxygen to be delivered by the blood to the muscular system.

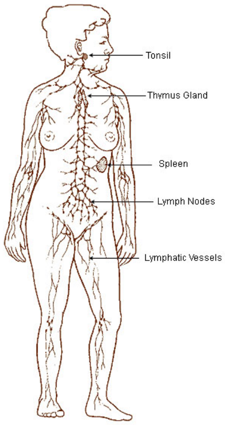
One of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

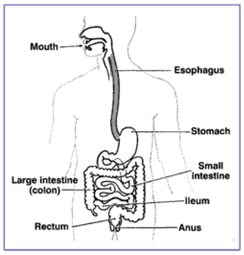
Table 5.1: **Major Organ Systems of the Human Body**

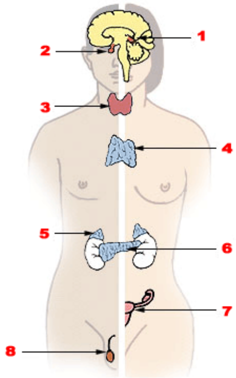
Organ System	Major Tissues and Organs	Function
Cardiovascular	Heart; blood vessels; blood	Transports oxygen, hormones and nutrients to the body cells. Moves wastes and carbon dioxide away from cells
Lymphatic	Lymph nodes; lymph vessels	Defense against infection and disease, moves lymph between tissues and the blood stream
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water
Endocrine	Pituitary gland, hypothalamus; adrenal glands; Islets of Langerhans; ovaries; testes	Hormones communicate between cells to maintain homeostasis
Integumentary	Skin, hair, nails	Protection from injury and water loss; physical defense against infection by microorganisms; temperature control
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons	Movement, support, heat production
Nervous	Brain, spinal cord; nerves	Collects, transfers and processes information
Reproductive	Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles	Production of gametes (sex cells) and sex hormones; production of offspring
Respiratory	Trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs)
Skeletal	Bones, cartilage; ligaments	Supports and protects soft tissues of body; movement at joints; produces blood cells; stores minerals
Urinary	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; control of pH; controls water and salt balance
Immune	Skin; bone marrow; spleen; white blood cells	Defense against diseases

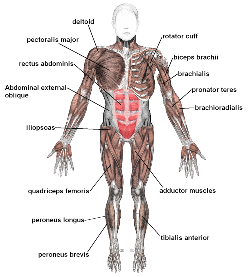
Organ System Cardiovascular Lymphatic Digestive Endocrine Integumentary Muscular Nervous Reproductive Respiratory Skeletal Urinary Immune Example

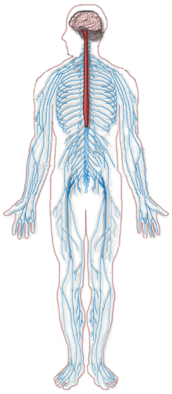


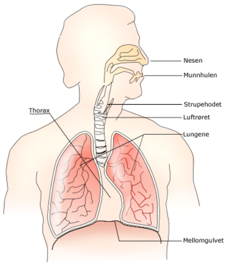


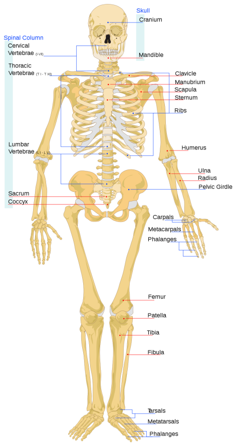


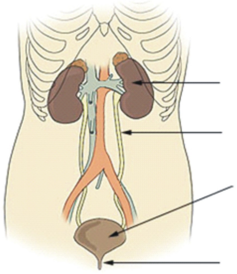












You can watch overviews of the human organ systems at the link below.

- `http://www.youtube.com/watch?v=KidJ-2H0nyY&#38;feature=player_embedded#!`

Figure 5.5: Google Body Browser (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/489

Homeostasis and Feedback Regulation

As described above, homeostasis is an organism's ability to keep a constant internal environment. Keeping a stable internal environment requires constant adjustments as conditions change inside and outside of cells.

The endocrine system plays an important role in homeostasis because hormones, which are the messengers of the endocrine system, regulate the activity of body cells. The release of hormones into the blood is controlled by a stimulus, or signal. For example, the stimulus either causes an increase or a decrease in the amount of hormone released. Then, the response to the signal changes the internal conditions and may itself become a new stimulus. This kind of control is called feedback regulation or a feedback loop.

Feedback regulation occurs when the response to a stimulus has an effect of some kind on the original stimulus. The type of response determines what the feedback is called. Take the men jumping in the water as an example. When the nervous system reduced blood flow to the skin, this was caused by a feedback loop sensing the change in environment. Feedback loops return body systems back to "normal."

A **negative feedback loop** is one in which the response to a stimulus decreases the effect of the original stimulus. A **positive feedback loop** is one in which the response to a stimulus increases the original stimulus. These are explained in more detail below.

Thermoregulation: A Negative Feedback Loop

Negative feedback is the most common feedback loop in the body. Negative feedback decreases the effect of a stimulus on the body (**Figure** 5.6). For instance, if you get stuck in a smoky environment during a fire, the amount of carbon dioxide in your body will increase. In the negative feedback loop, your lungs will be signaled to increase your breathing rate and exhale more carbon dioxide. The effect is to reduce the amount of carbon dioxide in your body. You can remember that this is a negative feedback loop because you are decreasing the effect of the stimulus.

Thermoregulation is another example of negative feedback. When body temperature rises, receptors in the skin and the brain sense the temperature change. The temperature change triggers a command from the brain. This command causes a response — the skin makes sweat and blood vessels near the skin surface dilate. This response helps decrease body temperature.

Positive feedback is less common than negative feedback. Positive feedback acts to increase the effect of a stimulus. An example of positive feedback is milk production. As the baby drinks its mother's milk, nerve messages from the mammary glands cause a hormone, prolactin, to be released. The more the baby suckles, the more prolactin is released, which causes more milk to be produced.

Lesson Summary

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- A tissue is a group of cells that work together.
- An organ is made of two or more tissues that work together.
- Organs that work together make up organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.
- There are 12 major organ systems in the body.
- Organs and organ systems work together to maintain homeostasis.

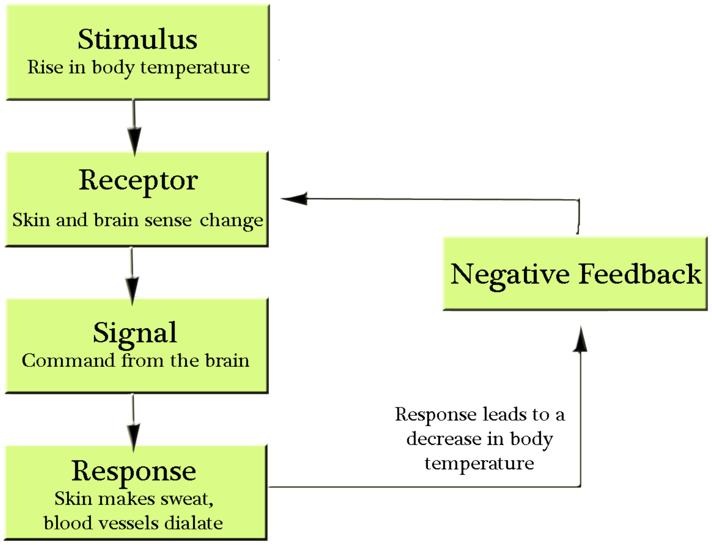


Figure 5.6: Feedback Regulation.

Review Questions

Recall

1. What is homeostasis?
2. What are the four levels of organization in an organism?
3. List the four types of tissues that make up the human body.

Apply Concepts

4. What is the difference between a tissue and an organ?
5. Identify the organ system to which the following organs belong: skin, stomach, brain, lungs, and heart.
6. Give an example of how two organ systems work together to maintain homeostasis.

Critical Thinking

7. A classmate says that all four tissue types are never found together in an organ. Do you agree with your classmate? Explain your answer.
8. Why do you think an organ is able to do many more jobs than a single tissue?

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Tissue_%28biology%29

Points to Consider

The first system we will discuss is the integumentary system.

- What organs do you think makes up the integumentary system?
- What other body systems might the integumentary system work with to maintain homeostasis?

5.2 The Integumentary System

Lesson Objectives

- List the functions of skin.
- Describe the structure of skin.
- Describe the structure of hair and nails.
- Identify two types of skin problems.
- Describe two ways to take care of your skin.

Check Your Understanding

- What is homeostasis?
- What is epithelial tissue?

Vocabulary

dermis epidermis integumentary system
keratin melanin' oil gland
sunburn sweat gland

Your Skin and Homeostasis

Did you know that you see the largest organ in your body every day? You wash it, dry it, cover it up to stay warm or uncover it to cool off. In fact, you see it so often it is easy to forget the important role your skin plays in keeping you healthy.

Your skin is part of your **integumentary system** (**Figure** 5.7), which is the outer covering of your body. The integumentary system is made up of your skin, hair, and nails. Your integumentary system has many roles in homeostasis, including protection, the sense of touch, and controlling body temperature.

Functions of Skin

Your skin covers the entire outside of your body. Your skin is your body's largest organ, yet it is only about 2 millimeters thick. It has many important functions. The skin:

- Provides a barrier. It keeps organisms that could harm the body out. It stops water from leaving the body, and stops water from getting into the body.

Figure 5.7: Skin acts as a barrier that stops water and other things, like soap and dirt, from getting into your body.

- Controls body temperature. It does this by making sweat, a watery substance that cools the body when it evaporates.
- Gathers information about your environment. Special nerve endings in your skin sense heat, pressure, cold and pain.
- Helps the body get rid of some types of waste, which are removed in sweat.
- Acts as a sun block. A chemical called melanin is made by certain skin cells when they are exposed to sunlight. Melanin blocks sun light from getting to deeper layers of skin cells, which are easily damaged by sunlight.

Structure of Skin

Your skin is always exposed to your external environment, so it gets cut, scratched, and worn down. You also naturally shed many skin cells every day. Your body replaces damaged or missing skin cells by growing more of them. Did you know that the layer of skin you can see is actually dead? The dead cells are filled with a tough, waterproof protein called **keratin**. As the dead cells are shed or removed from the upper layer, they are replaced by the skin cells below them.

As you can see in **Figure** 5.8, two different layers make up the skin — the epidermis and the dermis. A fatty layer, called subcutaneous tissue, lies under the dermis, but it is not part of your skin.

The color, thickness and texture of skin vary over the body. There are two general types of skin:

1. Thin and hairy, which is the most common type on the body.
2. Thick and hairless, which is found on parts of the body that experience a lot of contact with the environment, such as the palms of the hands or the soles of the feet.

The Epidermis

The **epidermis** is the outermost layer of the skin. It forms the waterproof, protective wrap over the body's surface. The epidermis is divided into several layers of epithelial cells. The epithelial cells are formed by mitosis in the lowest layer. These cells move up through the layers of the epidermis to the top. Although

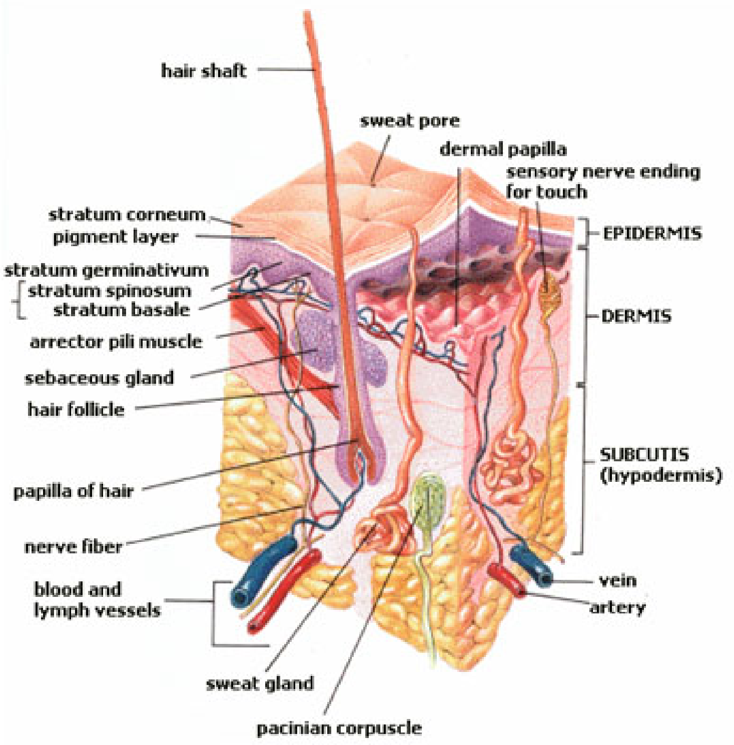


Figure 5.8: Skin is made up of two layers, the epidermis on top and the dermis below. The tissue below the dermis is called the hypodermis, but it is not part of the skin.

the top layer of epidermis is only about as thick as a sheet of paper, it is made up of 25 to 30 layers of cells.

The epidermis also contains cells that produce melanin. **Melanin** is the brownish pigment that gives skin and hair their color. Melanin-producing cells are found in the bottom layer of the epidermis.

The epidermis does not have any blood vessels. The lower part of the epidermis receives blood by diffusion from blood vessels of the dermis.

The Dermis

The **dermis** is the layer of skin directly under the epidermis. It is made of a tough connective tissue that contains the protein collagen. Collagen is a long, fiber-like protein that is very strong. The dermis is tightly connected to the epidermis by a thin wall of collagen fibers.

As you can see in **Figure** 5.8, the dermis contains hair follicles, sweat glands, oil glands, and blood vessels. It also holds many nerve endings that give you your sense of touch, pressure, heat, and pain.

Do you ever notice how your hair stands up when you are cold or afraid? Tiny muscles in the dermis pull on hair follicles which cause hair to stand up. The resulting little bumps in the skin are commonly called "goosebumps," shown in **Figure** 5.9.

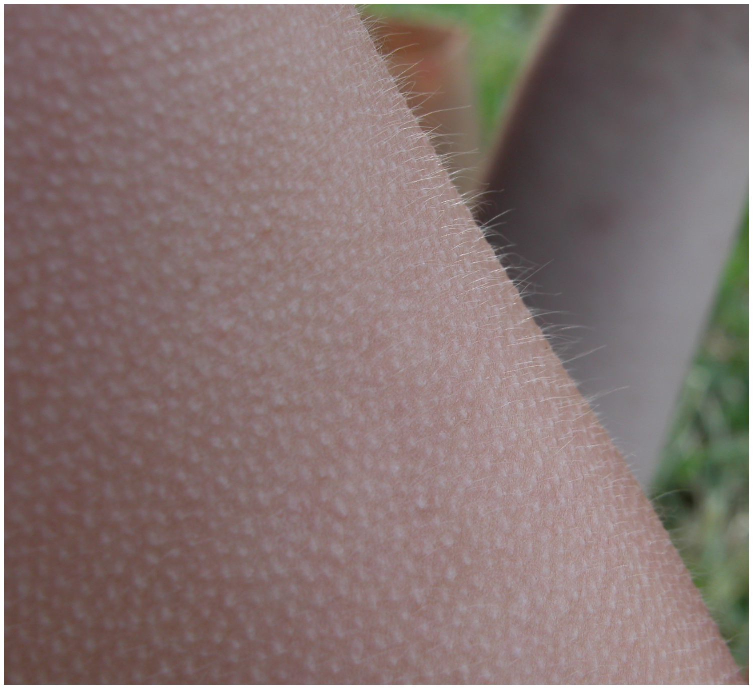


Figure 5.9: Goosebumps are caused by tiny muscles in the dermis that pull on hair follicles, which causes the hairs to stand up straight.

Oil Glands and Sweat Glands

Glands and follicles open out into the epidermis, but they start in the dermis. **Oil glands** release, or secrete, an oily substance, called sebum, into the hair follicle. An oil gland is shown in **Figure** 5.8. Sebum "waterproofs" hair and the skin surface to prevent them from drying out. It can also stop the growth of bacteria on the skin. It is odorless, but the breakdown of sebum by bacteria can cause odors. If an oil gland becomes plugged and infected, it develops into a pimple. Up to 85% of teenagers get pimples, which usually go away by adulthood. Frequent washing can help decrease the amount of sebum on the skin.

Sweat glands open to the skin surface through skin pores. They are found all over the body. Evaporation of sweat from the skin surface helps to lower skin temperature. This is why sweat can help maintain homeostasis. The skin also releases excess water, salts, and other wastes in sweat. A sweat gland is shown in **Figure** 5.8.

Nails and Hair

Nails and hair are made of the same types of cells that make up skin. Hair and nails contain the tough protein keratin.

Nails

Fingernails and toenails both grow from nail beds. A nailbed is thickened to form a lunula, or little moon, which you can see in **Figure** 5.10. Cells forming the nail bed are linked together to form the nail. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail, which is a good thing, otherwise cutting your nails would hurt a lot!

Nails act as protective plates over the fingertips and toes. Fingernails also help in sensing the environment. The area under your nail has many nerve endings, which allow you to receive more information about objects you touch. Nails are made up of many different parts, as shown in **Figure** 5.10.

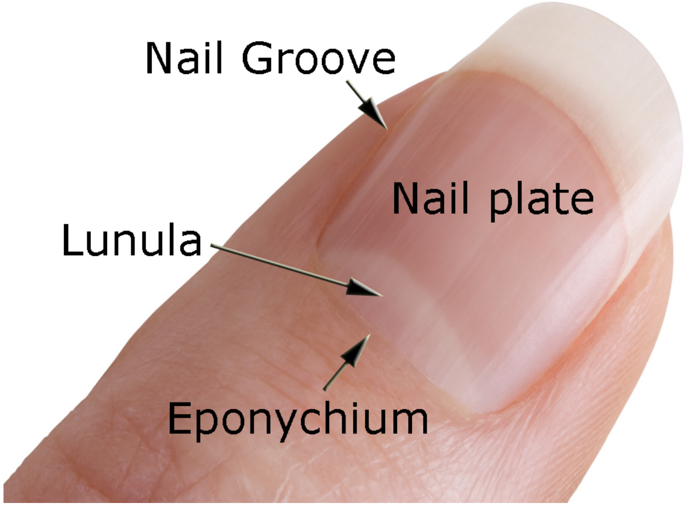


Figure 5.10: The structure of fingernails is similar to toenails. The free edge is the part of the nail that extends past the finger, beyond the nail plate. The nail plate is what we think of when we say “nail,” the hard portion made of the tough protein keratin. The lunula is the crescent shaped whitish area of the nail bed. The cuticle is the fold of skin at the end of the nail.

Hair

Hair sticks out from the epidermis, but it grows from the dermis, as shown in **Figure** 5.11. Hair is also made of keratin, the same protein that makes up skin and nails. Hair grows from inside the hair follicle. New cells grow in the bottom part of the hair, called the bulb. Older cells get pushed up, and the hair grows longer. Similar to nails and skin, the cells that make up the hair strand are dead and filled with keratin.

Hair color is caused by different types of melanin in the hair cells. In general, the more melanin in the cells, the darker the hair color; the less melanin, the lighter the hair color.

Hair helps to keep the body warm. When you feel cold, your skin gets a little bumpy. These bumps are caused by tiny muscles that pull on the hair, causing the hair to stick out. The erect hairs help to trap a thin layer of air that is warmed by body heat. In mammals that have much more hair than humans, the hair traps a layer of warm air near the skin and acts like warm blanket. Hair also protects the skin from ultraviolet (UV) radiation from the sun.

Hair also acts as a filter. Nose hair helps to trap particles in the air that may otherwise travel to the lungs. Eyelashes shield eyes from dust and sunlight. Eyebrows stop salty sweat and rain from flowing into the eye.

Keeping Skin Healthy

Some sunlight is good for health. Vitamin D is made in the skin when it is exposed to sunlight. But getting too much sun can be unhealthy. A **sunburn** is a burn to the skin that is caused by overexposure

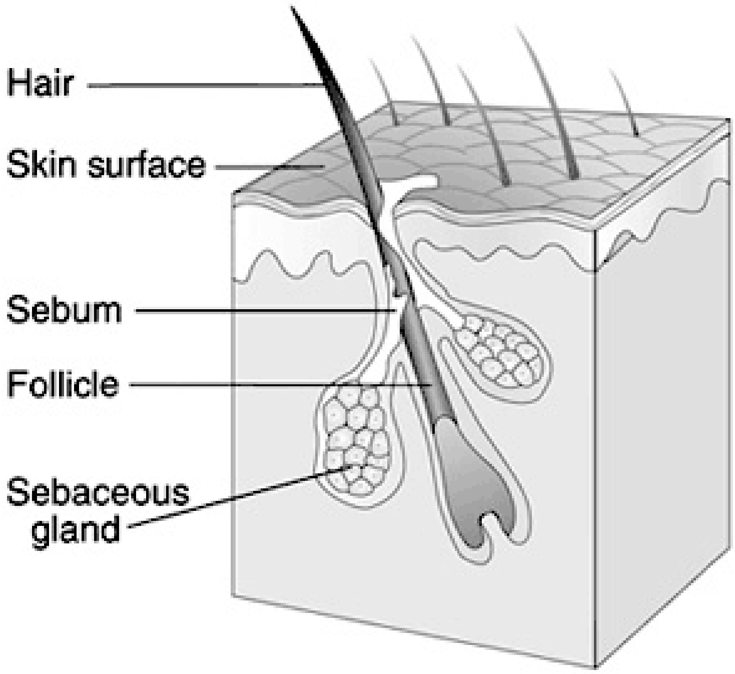


Figure 5.11: Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin.

to UV radiation from the sun's rays or tanning beds.

Light-skinned people, like the girl in **Figure** 5.12, get sunburned more quickly than people with darker skin. This is because melanin in the skin acts as a natural sunblock that helps to protect the body from UV radiation. When exposed to UV radiation, certain skin cells make melanin, which causes skin to tan. Children and teens who have gotten sunburned are at a greater risk of developing skin cancer later in life.

Long-term exposure to UV radiation is the leading cause of skin cancer. About 90 percent of skin cancers are linked to sun exposure. UV radiation damages the genetic material of skin cells. This damage can cause the skin cells to grow out of control and form a tumor. Some of these tumors are very difficult to cure. For this reason you should always wear sunscreen with a high sun protection factor (SPF), a hat, and clothing when out in the sun. As people age, their skin gets wrinkled. Wrinkles are caused mainly by UV radiation and by the loosening of the connective tissue in the dermis due to age.

Bathing and Skin Hygiene

During the day, your skin can collect many different things. Sweat, oil, dirt, dust, and dead skin cells can build up on the skin surface. If not washed away, the mix of sweat, oil, dirt, and dead skin cells can encourage the excess growth of bacteria. These bacteria feed on these substances and cause a smell that is commonly called body odor. Dirty skin is also more prone to infection. Bathing every day helps to remove dirt, sweat and extra skin cells, and helps to keep your skin clean and healthy.

Injury

Your skin can heal itself even after a large cut. Cells that are damaged or cut away are replaced by cells that grow in the bottom layer of the epidermis and the dermis. When an injury cuts through the epidermis

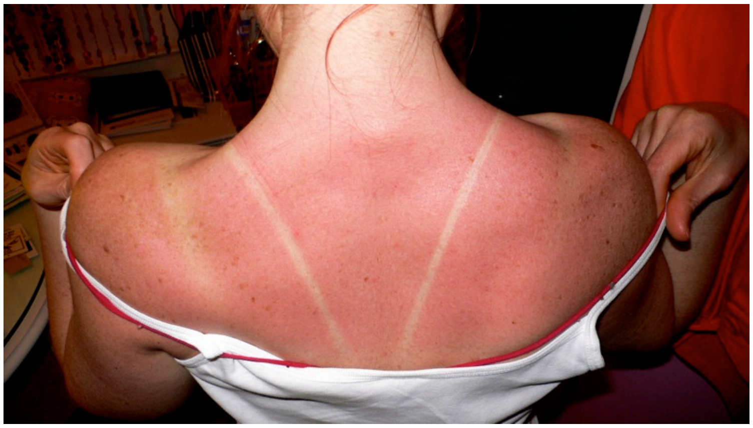


Figure 5.12: Sunburn is caused by overexposure to UV rays. Getting sunburned as a child or a teen, especially sunburn that causes blistering, increases the risk of developing skin cancer later in life.

into the dermis, bleeding occurs. A blood clot and scab soon forms. After the scab is formed, cells at the bottom of the epidermis begin to divide by mitosis and move to the edges of the scab. A few days after the injury, the edges of the wound are pulled together.

If the cut is large enough, the production of new skin cells will not be able to heal the wound. Stitching the edges of the injured skin together can help the skin to repair itself. The person in **Figure** 5.13 had a large cut that needed to be stitched together. When the damaged cells and tissues have been replaced, the stitches can be removed.

Lesson Summary

- Skin acts as a barrier that keeps particles and water out of the body.
- The skin helps to cool the body in hot temperatures, and keep the body warm in cool temperatures.
- Skin is made up of two layers, the epidermis and the dermis.
- Pimples occur when the skin produces too much sebum.
- Hair and nails are made of keratin, the same protein as skin.
- Nails grow from nail beds and hairs grow from hair follicles in the skin.
- Skin cancer can be caused by excess exposure to ultraviolet light from the sun or tanning beds.
- Frequent bathing helps keep the skin clean and healthy.
- Wearing sun block and a hat when outdoors can help prevent skin cancer.

Review Questions

Recall

1. Identify two functions of skin.
2. How does the integumentary system help maintain homeostasis?
3. What are the two layers of the skin?
4. Identify the layer of skin from which hair grows.
5. Name two functions of nails.
6. Name two functions of hair.

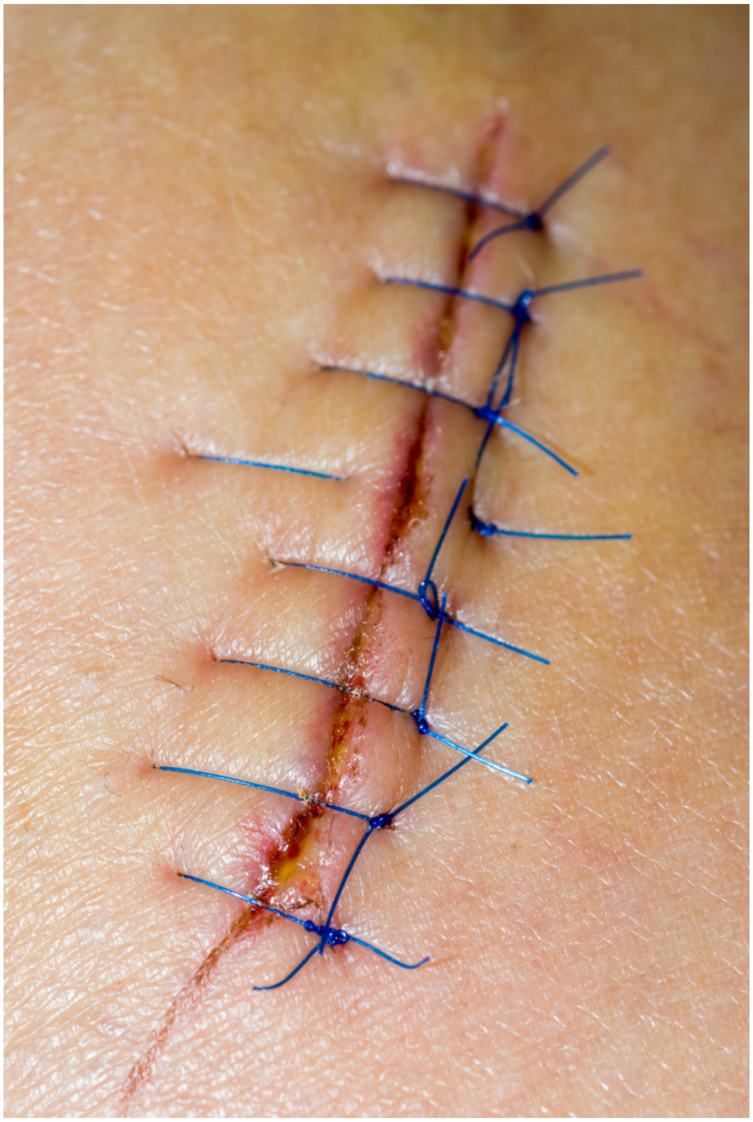


Figure 5.13: Sewing the edges of a large cut together allows the body to repair the damaged cells and tissues, and heal the tear in the skin.

Apply Concepts

7. In what way are hair and nails similar to skin?

8. The skin makes too much sebum, what type of skin problem might this cause?

9. How does washing your skin help to keep you healthy?

10. Why are stitches sometimes needed if a person gets a deep or long cut in their skin?

Critical Thinking

11. The World Health Organization recommends that no person younger than 18 years old use a tanning bed. Why do you think using a tanning bed is not recommended?

Further Reading / Supplemental Links

- `http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5540a9.htm`
- `http://www.cdc.gov/Features/SkinCancer`
- `http://en.wikipedia.org/wiki`

Points to Consider

Next we turn to the skeletal system.

- How might what you eat affect your bones?
- What do you think is the most important function of your skeletal system?

5.3 The Skeletal System

Lesson Objectives

- Identify the main tissues and organs of the skeletal system.
- List four functions of the skeletal system.
- Describe three movable joints.
- Identify two nutrients that are important for a healthy skeletal system.
- Describe two skeletal system injuries.

Check Your Understanding

- What is an organ system?
- What is connective tissue?

Vocabulary

ball and socket joint bone marrow cartilage
fracture gliding joint hinge joint

joint ligament movable joint
pivot joint skeletal system skeleton
sprain

Your Skeleton

How important is your skeleton? Can you imagine your body without it? You would be a wobbly pile of muscle and internal organs, and you would not be able to move.

Your skeleton is important for many different things. Bones are the main organs of the skeletal system. They are made up of living tissue. Humans are vertebrates, which are animals that have a backbone. The sturdy set of bones and cartilage that is found inside vertebrates is called a **skeleton**.

The adult human skeleton has 206 bones, some of which are named in **Figure** 5.14. Strangely, even though they are smaller, the skeletons of babies and children have many more bones and more cartilage than adults have. As a child grows, these “extra” bones grow into each other, and cartilage slowly hardens to become bone tissue.

Living bones are full of life. They contain many different types of tissues. **Cartilage** is found at the end of bones and is made of tough protein fibers called collagen. Cartilage creates smooth surfaces for the movement of bones that are next to each other, like the bones of the knee.

Ligaments are made of tough protein fibers and connect bones to each other. Your bones, cartilage, and ligaments make up your **skeletal system**.

Functions of Bones

Your skeletal system gives shape and form to your body, but it is also important in maintaining homeostasis. The main functions of the skeletal system include:

- Support. The skeleton supports the body against the pull of gravity, meaning you don’t fall over when you stand up. The large bones of the lower limbs support the rest of the body when standing.
- Protection. The skeleton supports and protects the soft organs of the body. For example, the skull surrounds the brain to protect it from injury. The bones of the rib cage help protect the heart and lungs.
- Movement. Bones work together with muscles to move the body.
- Making blood cells. Blood cells are mostly made inside certain types of bones.
- Storage. Bones store calcium. They contain more calcium than any other organ. Calcium is released by the bones when blood levels of calcium drop too low. The mineral phosphorus is also stored in bones.

Structure of Bones

Bones are organs. Recall that organs are made up of two or more types of tissues. Bones come in many different shapes and sizes, but they are all made of the same materials.

The two main types of bone tissue are compact bone and spongy bone.

- Compact bone makes up the dense outer layer of bones.

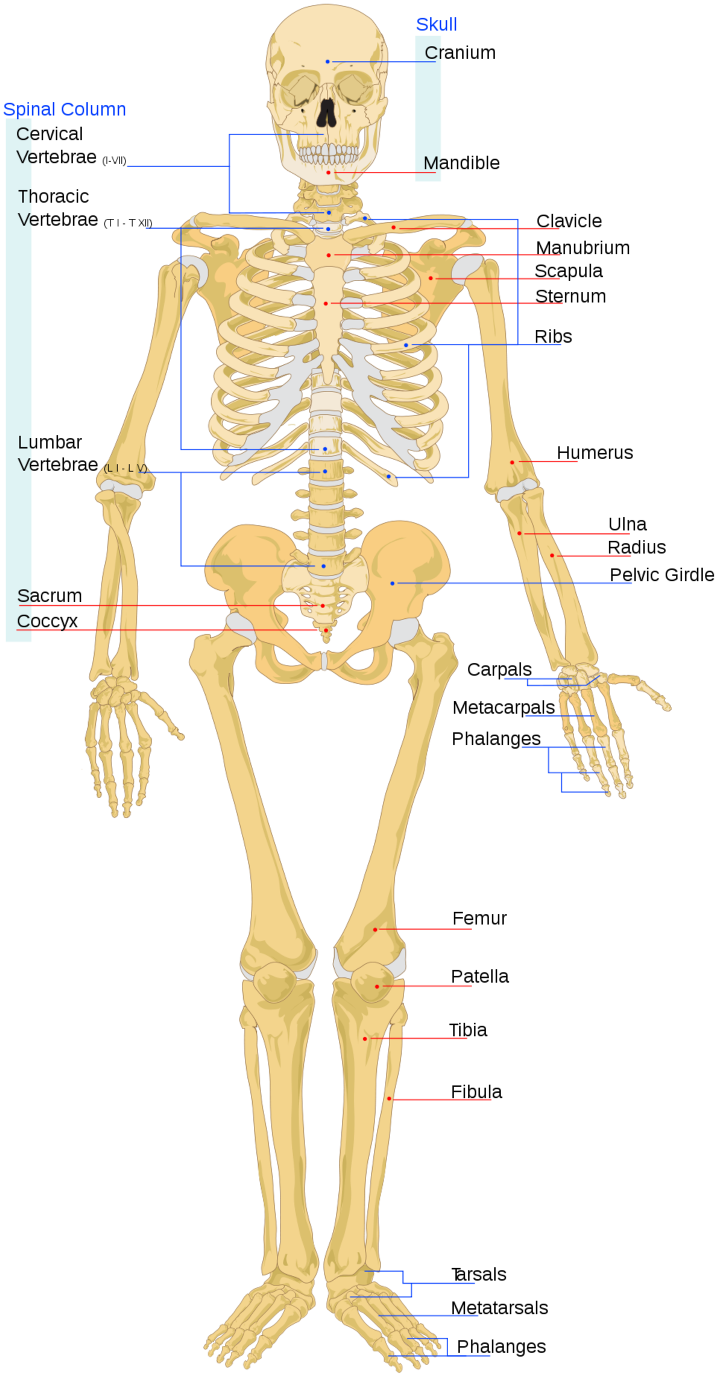


Figure 5.14: The skeletal system is made up of bones, cartilage, and ligaments. The skeletal system has many important functions in your body.

- Spongy bone is found at the center of the bone, and is lighter and less dense than compact bone.

Bones look tough, shiny, and white because they are covered by a layer called the periosteum. Many bones also contain a soft connective tissue called **bone marrow**. There are two types of bone marrow - red marrow and yellow marrow.

- Red marrow makes red blood cells, platelets, and most of the white blood cells for the body (discussed in the *Diseases and the Body's Defenses* chapter).
- Yellow marrow makes white blood cells.

The bones of newborn babies contain only red marrow. As children get older, some of their red marrow is replaced by yellow marrow. In adults, red marrow is found mostly in the bones of the skull, the ribs, and pelvic bones.

Bones come in four main shapes. They can be long, short, flat, or irregular. Identifying a bone as long, short, flat, or irregular is based on the shape of the bone, not the size of the bone. For example, both small and large bones can be classified as long bones. The small bones in your fingers and the largest bone in your body, the femur, are all long bones. The structure of a long bone is shown in **Figure** 5.15.

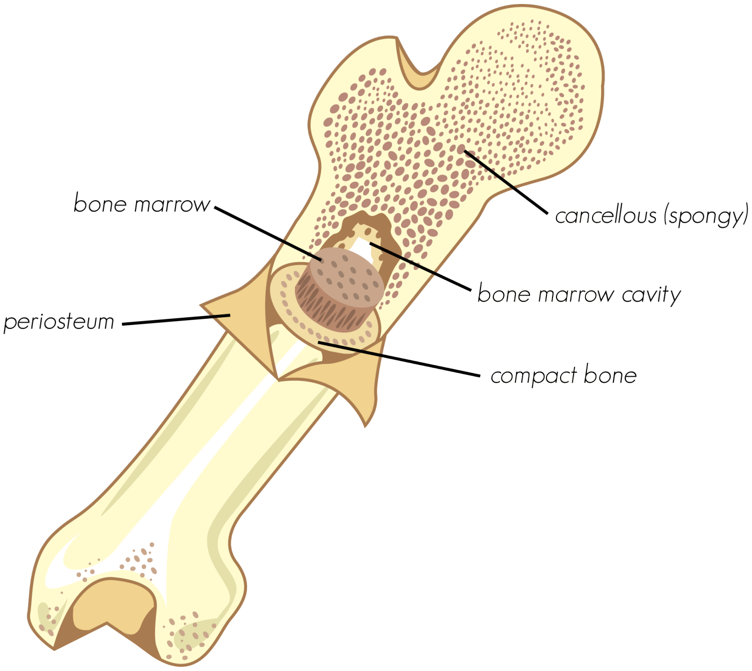


Figure 5.15: Bones are made up of different types of tissues.

Bone Growth

Your skeleton begins growing very early in development. After only eight weeks of growth from a fertilized egg, your skeleton has been formed by cartilage and other connective tissues.

At this point your skeleton is very flexible. After a few more weeks of growth, the cells that form hard bone begin growing in the cartilage, and your skeleton begins to harden. Not all of the cartilage, however, is replaced by bone. Cartilage remains in many places in your body, including your joints, your rib cage, your ears, and the tip of your nose.

A baby is born with zones of cartilage in its bones that allow growth of the bones. These areas, called growth plate, allow the bones to grow longer as the child grows. By the time the child reaches an age of about 18 to 25 years, all of the cartilage in the growth plate has been replaced by bone. This stops the bone from growing any longer.

Even though bones stop growing in length in early adulthood, they can continue to increase in thickness throughout life. This thickening occurs in response to strain from increased muscle activity and from weight-lifting exercises.

Joints and How They Move

A **joint** is a point at which two or more bones meet. There are three types of joints in the body:

1. Fixed joints do not allow any bone movement. Many of the joints in your skull are fixed (**Figure** 5.16).
2. Partly movable joints allow only a little movement. Your backbone has partly movable joints between the vertebrae (**Figure** 5.17).
3. **Movable joints** allow movement.

Joints are a type of lever, which is a rigid object that is used to increase the amount of force put onto another object. Can openers and scissors are examples of levers. Joints reduce the amount of energy that is spent moving the body around. Just imagine how difficult it would be to walk about if you did not have knees!

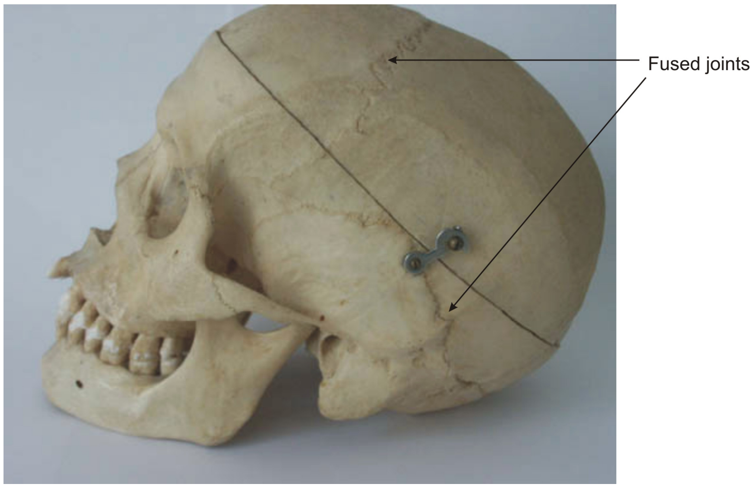


Figure 5.16: The skull has fixed joints. Fixed joints do not allow any movement of the bones, which protects the brain from injury.

Movable Joints

Movable joints are the most mobile joints of all. They are also the most common type of joint in your body. Your fingers, toes, hips, elbows, and knees all provide examples movable joints. The surfaces of bones at movable joints are covered with a smooth layer of cartilage. The space between the bones in a movable joint is filled with a liquid called synovial fluid. Synovial fluid is a thick, stringy fluid that looks like egg white. The fluid gives the bone a smooth cushion when they move at the joint. Four types of movable joints are shown below.

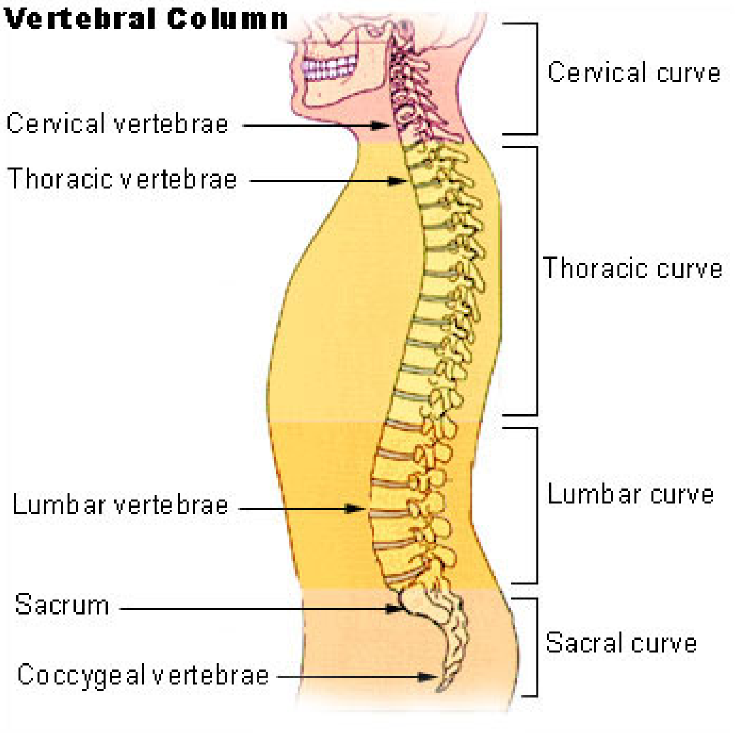


Figure 5.17: The joints between your vertebrae are partially movable.

1. In a **ball and socket joint**, the ball-shaped surface of one bone fits into the cup-like shape of another. Examples of a ball and socket joint include the hip, shown in **Figure** 5.18, and the shoulder.

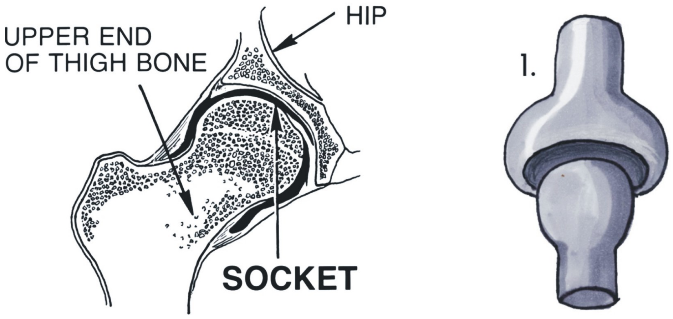


Figure 5.18: Ball and Socket Joint. Your hip joint is a ball and socket joint. The "ball" end of one bone fits into the "socket" of another bone. These joints can move in many different directions.

2. In a **hinge joint**, the ends of the bones are shaped in a way that allows motion only in two directions, forward and backward. Examples of hinge joints are the knees and elbows. A knee joint is shown in **Figure** 5.19.

3. The **pivot joint** is formed by a process that rotates within a ring, the ring being formed partly of bone and partly of ligament. An example of a pivot joint is the joint between the radius and ulna that allows you to turn the palm of your hand up and down. A pivot joint is shown in **Figure** 5.20.

4. A **gliding joint** is a joint which allows only gliding movement. The gliding joint allows one bone to slide over the other. The gliding joint in your wrist allows you to flex your wrist. It also allows you to make very small side-to-side motions. There are also gliding joints in your ankles.

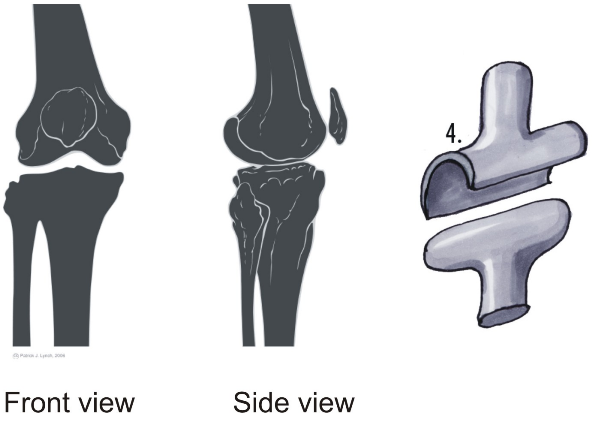


Figure 5.19: Hinge Joint. The knee joint is a hinge joint. Like a door hinge, a hinge joint allows backward and forward movement.

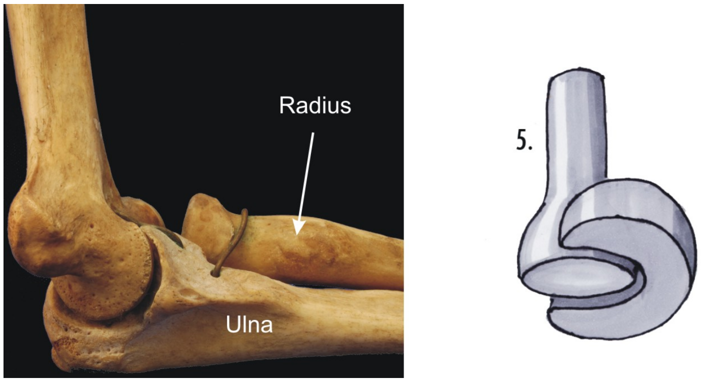


Figure 5.20: Pivot Joint. The joint at which the radius and ulna meet is a pivot joint. Movement at this joint allows you to flip your palm over without moving your elbow joint.

Keeping Bones and Joints Healthy

Your body depends on you to take care of it, just like you may take care of a plant or a dog. You can help keep your bones and skeletal system healthy by eating well and getting enough exercise. Weight-bearing exercises help keep bones strong. Weight-bearing exercises work against gravity. Such activities include basketball, tennis, gymnastics, karate, running, and walking. When the body is exercised regularly by performing weight-bearing activity, bones respond by adding more bone cells to increase their bone density.

Eating Well

Did you know that what you eat as a teenager can affect how healthy your skeletal system will be in 30, 40, and even 50 years? Calcium and vitamin D are two of the most important nutrients for a healthy skeletal system. Your bones need calcium to grow properly. If you do not get enough calcium in your diet as a teenager, your bones may become weak and break easily later in life.

Osteoporosis is a disease in which bones become lighter and more porous than they should be. Light and porous bones are more likely to break, which can cause pain and prevent a person from walking. Two of the easiest ways to prevent osteoporosis are eating a healthy diet that has the right amount of calcium and vitamin D, and to do some sort of weight-bearing exercise every day. Foods that are a good source of calcium include milk, yogurt, and cheese. Non-dairy sources of calcium include Chinese cabbage, kale, and broccoli. Many fruit juices, fruit drinks, tofu, and cereals have calcium added to them. It is recommended that teenagers get 1300 mg of calcium every day. For example, one cup of milk provides about 300 mg of calcium, or about 30% of the daily requirement. Other sources of calcium are shown in **Figure** 5.21.

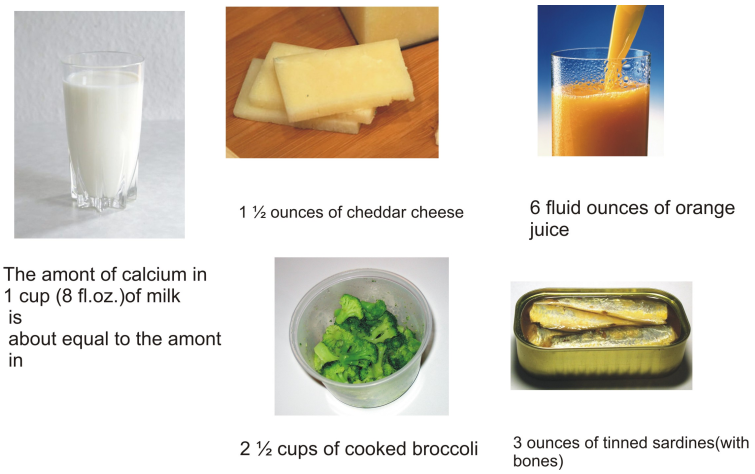

1 ½ ounces of cheddar cheese
6 fluid ounces of orange juice
The amont of calcium in
1 cup (8 fl.oz.)of milk
is
about equal to the amont
in
2 ½ cups of cooked broccoli
3 ounces of tinned sardines(with bones)

Figure 5.21: There are many different sources of calcium. Getting enough calcium in your daily diet is important for good bone health. How many ounces of cheddar cheese would provide your recommended daily intake of calcium?

Your skin makes vitamin D when exposed to sunlight. The pigment melanin in the skin acts like a filter that can prevent the skin from making vitamin D. As a result, people with darker skin need more time in the sun than people with lighter skin to make the same amount of vitamin D.

Fish is naturally rich in vitamin D. Vitamin D is added to other foods, including milk, soy milk, and breakfast cereals. Teenagers are recommended to get 5 micrograms (200 IU) of vitamin D every day. A 3½-ounce portion of cooked salmon provides 360 IU of vitamin D.

Bone Fractures

Even though they are very strong, bones can **fracture**, or break. Fractures can happen at different places on a bone. They are usually caused by excess bending stress on the bone. Bending stress is what causes a pencil to break if you bend it too far.

Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days bone cells travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving, and give the body a chance to repair the break. A broken ulna has been repaired with pins in **Figure** 5.22.

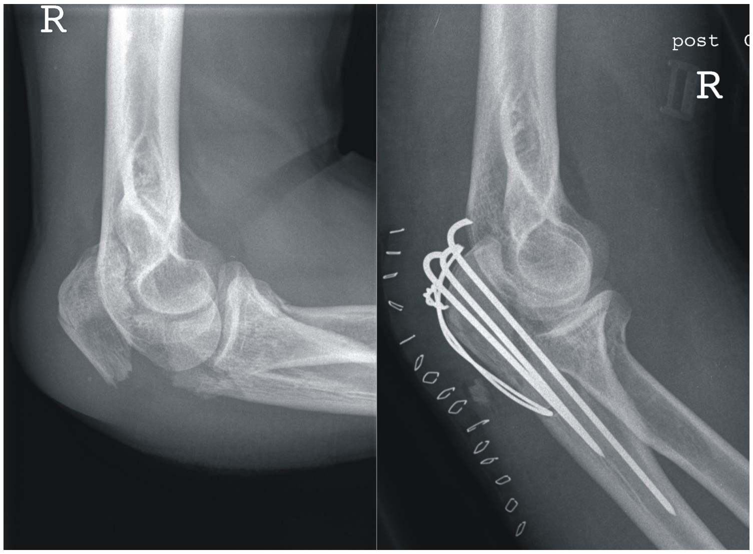


Figure 5.22: The upper part of the ulna, just above the elbow joint, is broken, as you can see in the X-ray at left. The x-ray at right was taken after a surgeon inserted a system of pins and wires across the fracture to bring the two pieces of the ulna into close proximity.

Cartilage Injuries

Osteoarthritis occurs when the cartilage at the ends of the bones breaks down. The break down of the cartilage leads to pain and stiffness in the joint. Decreased movement of the joint because of the pain may lead to weakening of the muscles that normally move the joint, and the ligaments surrounding the joint may become looser. Osteoarthritis is the most common form of arthritis. It has many causes, including aging, sport injuries, fractures, and obesity.

Ligament Injuries

Recall that a ligament is a short band of tough connective tissue that connects bones together to form a joint. Ligaments can get injured when a joint gets twisted or bends too far. The protein fibers that make up a ligament can get strained or torn, causing swelling and pain. Injuries to ligaments are called **sprains**. Ankle sprains are a common type of sprain. A sprain of the anterior cruciform ligament (ACL), a small ligament in the knee, is a common injury among athletes. Ligament injuries can take a long time to heal. Treatment of the injury includes rest and special exercises that are developed by a physical therapist.

Preventing Injuries

Preventing injuries to your bones and ligaments is easier and much less painful than treating an injury. Wearing the correct safety equipment when performing activities that require such equipment can help prevent many common injuries. For example, wearing a bicycle helmet can help prevent a skull injury if you fall. Warming up and cooling down properly can help prevent ligament and muscle injuries. Stretching before and after activity also helps prevent injuries. Stretching can improve your posture, and helps prevent some aches and pains associated with tight muscles.

Lesson Summary

- Bones, cartilage, and ligaments make up the skeletal system.
- The skeleton supports the body against the pull of gravity.
- The skeleton provides a framework that supports and protects the soft organs of the body.
- Bones work together with muscles to move the body.
- Blood cells are mostly made inside the bone marrow.
- There are three types of joints in the body: fixed, partly movable, and movable.
- Calcium and vitamin D are two of the most important nutrients for a healthy skeletal system.
- The break down of the cartilage leads to pain and stiffness in the joint.
- A sprain is an injury to a ligament.
- A fracture is a break or crack in a bone.

Review Questions

Recall

1. What are the main organs of the skeletal system?
2. Name one tissue of the skeletal system.
3. List four functions of the skeletal system.
4. Name three types of movable joints.
5. Name two things you can do to keep your skeletal system healthy.

Apply Concepts

6. "All joints in the body are movable." Do you agree with this statement? Explain why or why not.
7. How are the joints in your body similar to levers?
8. Why is calcium important for a healthy skeletal system?
9. The recommended daily amount of calcium for teenagers is 1300 mg. If a person gets only 1000 mg a day, what percentage of the recommended daily amount are they getting?
10. What part of the skeletal system does osteoarthritis affect?
11. Why might a doctor need to insert pins into a broken bone?

Critical Thinking

12. You are a doctor. An athlete comes to you with a torn ACL and asks you to give him a cast. Tell him why that is not the correct treatment for his injury.

Further Reading / Supplemental Links

- http://www.girlshealth.gov/bones
- [http://www.cdc.gov/nccdphp/dnpa/nutrition/nutrition_for_everyone/basics/calcium.htm http://www.cdc.gov/nccdphp/dnpa/nutrition/nutrition_for_everyone/basics/calcium.htm
- http://en.wikipedia.org/wiki

Points to Consider

Next we discuss the muscular system.

- How do you think your skeletal system interacts with your muscular system?
- How could a broken bone affect the functioning of the muscular system?

5.4 The Muscular System

Lesson Objectives

- Identify the three muscle types in the body.
- Describe how skeletal muscles and bones work together to move the body.
- Describe how exercise affects the muscular system.
- Identify two types of injuries to the muscular system.

Check Your Understanding

- What is muscle tissue?
- What is the function of the muscular system?

Vocabulary

aerobic exercises anaerobic exercise cardiac muscle
contraction extensor flexor
involuntary muscle muscle fibers muscular system
physical fitness skeletal muscle smooth muscle
strain tendon voluntary muscle

Types of Muscles

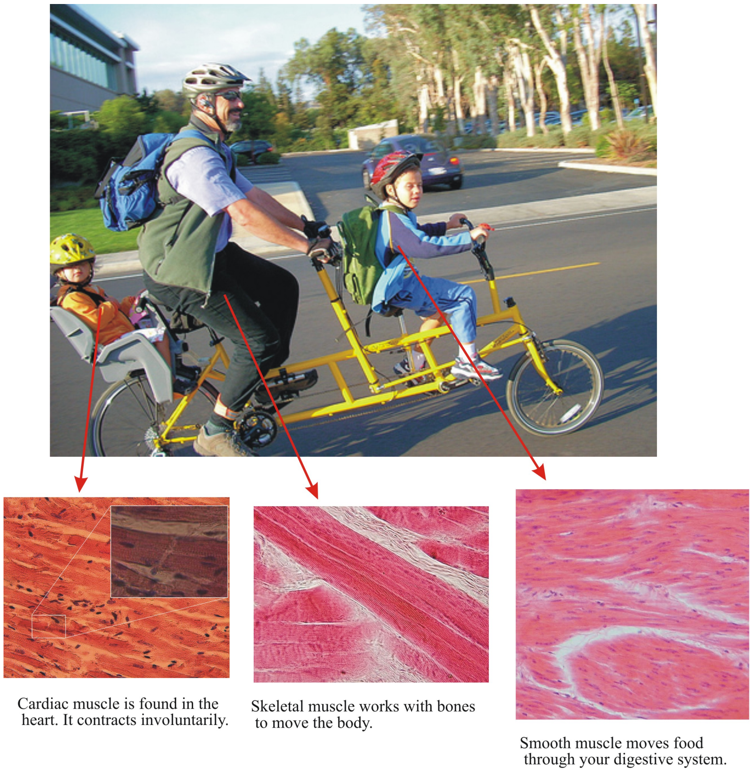
The **muscular system** is the body system that allows us to move. You depend on many muscles to keep you alive. Your heart, which is mostly muscle, pumps blood around your body. Muscles are always moving in your body.

Each muscle in the body is made up of cells called muscle fibers. **Muscle fibers** are long, thin cells that can do something that other cells cannot do — they are able to get shorter. Shortening of muscle fibers is called **contraction**. Nearly all movement in the body is the result of muscle contraction.

Certain muscle movements happen without you thinking about them, while you can control other muscle movements. Muscles that you can control are called **voluntary muscles**. Muscles that you cannot control are called **involuntary muscles**.

There are three different types of muscles in the body (**Figure** 5.23):

1. **Skeletal muscle** is made up of voluntary muscles, usually attached to the skeleton. Skeletal muscles move the body. They can also contract involuntarily by reflexes. For example, you can choose to move your arm, but your arm would move automatically if you were to burn your finger on a stove top.
2. **Smooth muscle** is composed of involuntary muscles found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels. Unlike skeletal muscle, smooth muscle can never be under your control.
3. **Cardiac muscle** is also an involuntary muscle, found only in the heart.


Cardiac muscle is found in the heart. It contracts involuntarily.

Skeletal muscle works with bones to move the body.

Smooth muscle moves food through your digestive system.

Figure 5.23: There are three types of muscles in the body: cardiac, skeletal, and smooth. Everyone has the same three types of muscle tissue, no matter their age.

Muscles, Bones, and Movement

Skeletal muscles are attached to the skeleton by tendons. A **tendon** is a tough band of connective tissue that connects a muscle to a bone. Tendons are similar to ligaments, except that ligaments join bones to each other.

Muscles move the body by contracting against the skeleton. When muscles contract, they get shorter. When they relax, they get longer. By contracting and relaxing, muscles pull on bones and allow the body to move. Muscles work together in pairs. Each muscle in the pair works against the other to move bones at the joints of the body. The muscle that contracts to cause a joint to bend is called the **flexor**. The muscle that contracts to cause the joint to straighten is called the **extensor**.

For example, the biceps and triceps muscles work together to allow you to bend and straighten your elbow. Your biceps muscle, shown in **Figure** 5.24, contracts, and at the same time the triceps muscle relaxes. The biceps is the flexor and the triceps is the extensor of your elbow joint. In this way the joints of your body act like levers. This lever action of your joints decreases the amount of energy you have to spend to make large body movements.

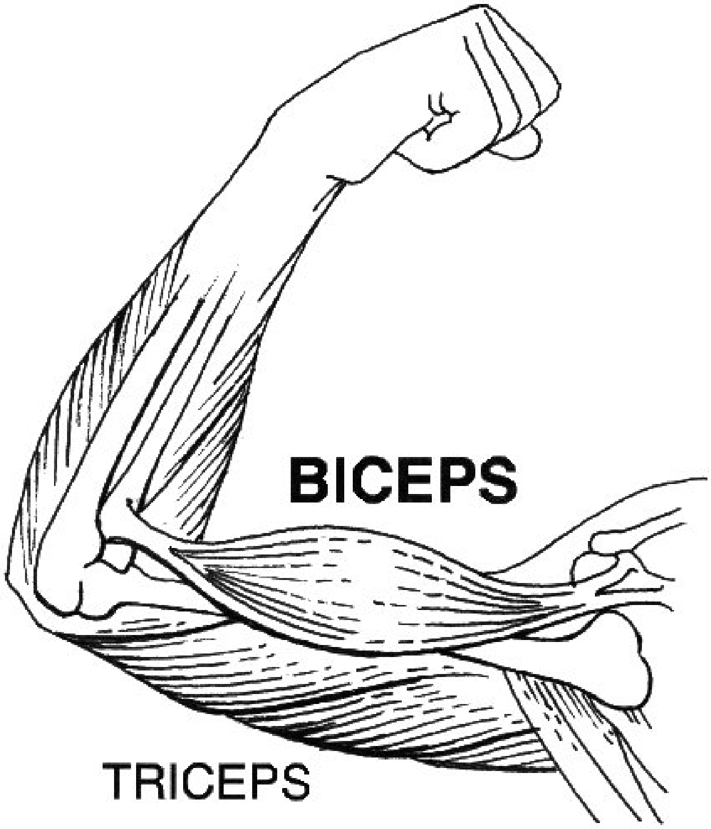


Figure 5.24: The biceps and triceps act against one another to bend and straighten the elbow joint. To bend the elbow, the biceps contract and the triceps relax. To straighten the elbow, the triceps contract and the biceps relax.

Muscles and the Nervous System

Muscles are controlled by the nervous system (see the *Controlling the Body* chapter). Nerves send messages to the muscular system from the brain. Nerves also send messages to the brain from the muscles. For example, when you want to move your foot, electrical messages called impulses move along nerve cells from your brain to the muscles of your foot. At the point at which the nerve cell and muscle cells meet, the electrical message is converted to a chemical message. The muscle cells receive the chemical message, which causes tiny protein fibers inside the muscle cells to get shorter. The muscles contract, pulling on the bones, and your foot moves.

Muscles and Exercise

Your muscles are important for carrying out everyday activities. The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired is called **physical fitness**. Physical exercise is any activity that maintains or improves physical fitness and overall health. Regular physical exercise is important in preventing lifestyle diseases such as heart disease, cardiovascular disease, Type 2 diabetes, and obesity. Regular exercise improves the health of the muscular system. Muscles that are exercised are bigger and stronger than muscles that are not exercised.

Exercise improves both muscular strength and muscular endurance. Muscular strength is the ability of a muscle to use force during a contraction. Muscular endurance is the ability of a muscle to continue to contract over a long time without getting tired.

Exercises are grouped into three types depending on the effect they have on the body:

- **Aerobic exercises**, such as cycling, walking, and running, increase muscular endurance.
- **Anaerobic exercises**, such as weight training or sprinting, increase muscle strength.
- Flexibility exercises, such as stretching, improve the range of motion of muscles and joints. Regular stretching helps avoid activity-related injuries.

Anaerobic Exercise and Muscular Strength

Anaerobic exercises cause muscles to get bigger and stronger. Anaerobic exercises use a resistance against which the muscle has to work to lift or push away. The resistance can be a weight or a person's own body weight, as shown in **Figure** 5.25. After many muscle contractions, muscle fibers build up larger energy stores and the muscle tissue gets bigger. The larger a muscle is, the greater the force it can apply to lift a weight or move a body joint. The muscles of weightlifters are large and strong.

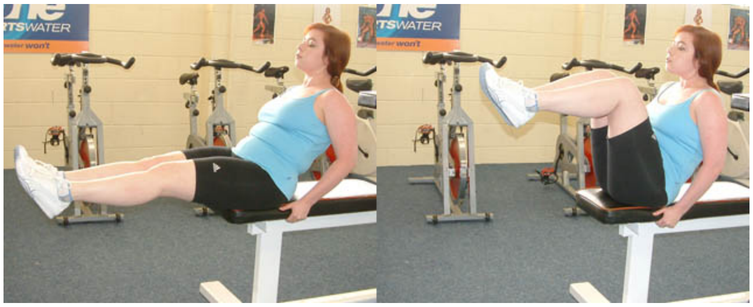


Figure 5.25: Anaerobic exercises involve the muscles working against resistance. In this case the resistance is the person's own body weight.

Aerobic Exercise and Muscular Endurance

Aerobic exercises are exercises that cause your heart to beat faster and allow your muscles to use oxygen to contract. Aerobic exercise causes many different changes in skeletal muscle. Muscle energy stores are increased and the ability to use oxygen improves. If you exercise aerobically, overtime, your muscles will not get easily tired and you will use oxygen and food more efficiently. Aerobic exercise also helps improve cardiac muscle. Overtime, the heart muscles will increase in size and be able to pump a larger volume of blood to your cells. Examples of an aerobic exercise are shown in **Figure** 5.26.

Figure 5.26: When done regularly, aerobic activities such as cycling, make the heart stronger.

Muscle Injuries

Sometimes muscles and tendons get injured when a person starts doing an activity before they have warmed up properly. A warm up is a slow increase in the intensity of a physical activity that prepares muscles for an activity. Warming up increases the blood flow to the muscles and increases the heart rate. Warmed-up muscles and tendons are less likely to get injured. For example, before running or playing soccer, a person might jog slowly to warm muscles and increase their heart rate. Even elite athletes need to warm up, as shown in **Figure** 5.27.

A **strain** happens when muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up. Strains are also known as ”pulled muscles.” Some injuries are caused by overuse. An overuse injury happens if the muscle or joint is not rested enough between activities. Overuse injuries often involve tendons. Overuse of tendons can cause tiny tears within the protein fibers of the tendon. These tiny tears lead to swelling, pain, and stiffness, a condition called tendinitis. Tendinitis can affect any tendon that is overused. Strains and tendinitis are usually treated with rest, cold compresses, and stretching exercises that a physical therapist designs for each patient.

Proper rest and recovery are also as important to health as exercise is. If you do not get enough rest, your body will become injured and will not improve or react well to exercise. You can also rest by doing a different activity. For example, if you run, you can rest your running muscles and joints by swimming. This type of rest is called ”active rest.”

Steroids

Anabolic steroids are hormones that cause the body to build up more protein in its cells. Muscle cells, which contain a lot of protein, get bigger when exposed to anabolic steroids. Your body naturally makes small amounts of anabolic steroids. They help your body repair from injury, and help to build bones and

Figure 5.27: Warming up before the game helps the players avoid injuries. Some warm-ups may include stretching exercises. Some researchers believe stretching before activities may help prevent injury.

muscles. Anabolic steroids are used as medicines to treat people that have illnesses that affect muscle and bone growth. But some athletes who do not need steroids take them to increase their muscle size. When taken in this way, anabolic steroids can have long-term affects other body systems. They can damage the person's kidneys, heart, liver, and reproductive system. If taken by adolescents, anabolic steroids can cause bones to stop growing, resulting in stunted growth.

Lesson Summary

- The body has three types of muscle tissue: skeletal, smooth, and cardiac.
- Muscles move the body by contracting against the skeleton.
- Muscles are controlled by the nervous system.
- Regular exercise improves the health of the muscular system and makes muscles bigger and stronger.
- Muscular strength is the ability of a muscle to exert force during a contraction.
- Muscular endurance is the ability of a muscle to continue to contract over a long time without getting tired.
- A strain is an injury to a muscle in which the muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up.
- Tiny tears and swelling in a tendon results in tendinitis.

Review Questions

Recall

1. Name the three types of muscle tissue in the body.
2. Which of the three types of muscles in the body is voluntary?
3. What is a tendon?
4. What is a muscle strain?

Apply Concepts

5. Describe how skeletal muscles and bones work together to move the body.
6. How does aerobic exercise affect the heart?
7. How does aerobic exercise affect skeletal muscle?
8. How does anaerobic exercise affect skeletal muscle?
9. Why is warming up before exercise a good idea?

Critical Thinking

10. A friend of yours says that taking steroids is not bad for their health because humans produce steroids in their body anyway. Can you explain to them why taking anabolic steroids is dangerous?

Further Reading / Supplemental Links

- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/index.htm
- http://en.wiki.org

Points to Consider

Next we move on to the digestive system.

- How does your muscular system depend on your digestive system?
- How does what you choose to eat affect your muscular system and your skeletal system?

Image Sources

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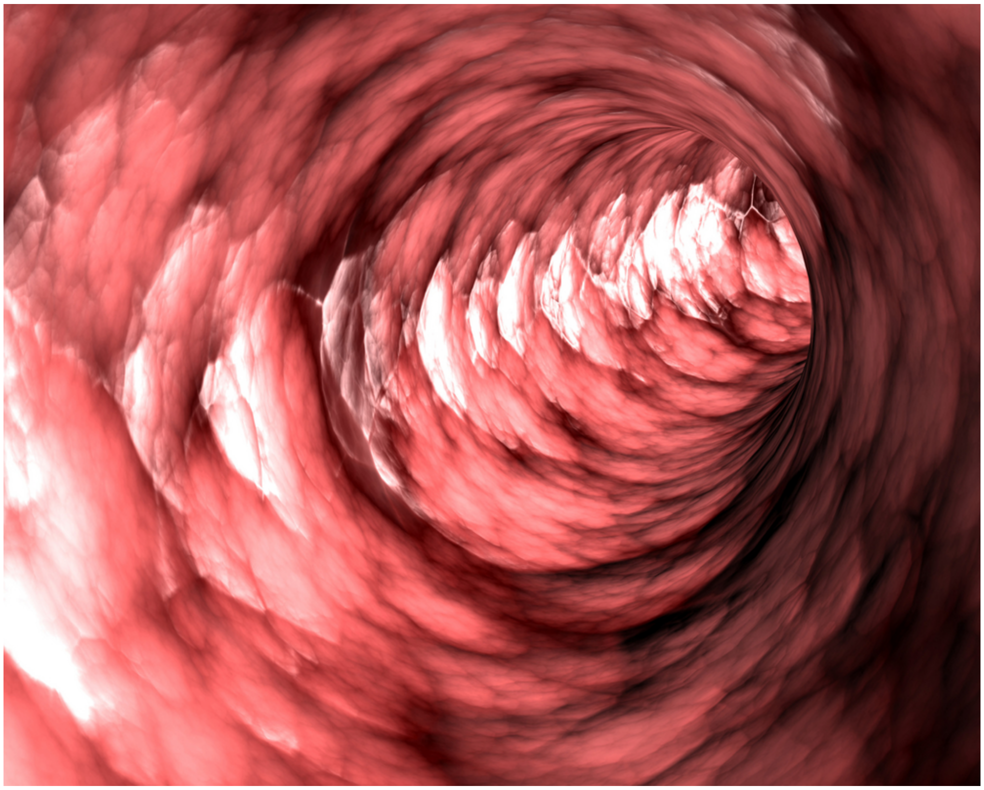
Chapter 6

MS Food and the Digestive System



The above image shows a close-up of the inside of a fleshy tunnel. Could it be an intestine? It could. Or it could be something else. But what is an intestine? It is an organ in the digestive system. The digestive system does what you think it does - it digests your food.

But does the inside of your intestine really look like a tunnel? Some would say an intestine looks more like a mountain range, with peaks and valleys. Why? The peaks and valleys would represent the villi that are inside of the intestines. They increase the surface area of the intestine so they can absorb as many nutrients as possible.

So what is another function of the digestive system? Absorption. What happens when you get sick? Does the digestive system work properly? What nutrients and vitamins do you need in order to make sure that your digestive system and your whole body works properly? What do the villi in the intestines have to do with these processes? As you read, think about the organs that help you digest and absorb the nutrients in your foods. Also, consider how healthy eating leads to healthy organ systems.

6.1 Food and Nutrients

Lesson Objectives

- Explain why the body needs food.
- Identify the roles of carbohydrates, proteins, and lipids.
- Give examples of vitamins and minerals, and state their functions.
- Explain why water is a nutrient.

Check Your Understanding

- What are the four types of organic compounds?
- What do all cells need in order to function?
- What are muscles made of?

Vocabulary

calorie essential amino acids minerals
nutrients starch trans fat
vitamins

Why We Need Food

Did you ever hear the old saying “An apple a day keeps the doctor away”? Do apples really prevent you from getting sick? Probably not, but eating apples and other fresh fruits can help keep you healthy. The girl shown in **Figure** 6.1 is eating fresh vegetables as part of a healthy meal. Why do you need foods like these for good health? What role does food play in the body?

Your body needs food for three reasons:

1. Food gives your body energy. You need energy for everything you do.
2. Food provides building materials for your body. Your body needs building materials so it can grow and repair itself.
3. Food contains substances that help control body processes. Your body processes must be kept in balance for good health.

For all these reasons, you must have a regular supply of nutrients. **Nutrients** are chemicals in food that your body needs. There are six types of nutrients:

1. Carbohydrates.
2. Proteins.

Figure 6.1: This girl is eating a salad of tomatoes and leafy green vegetables. Fresh vegetables such as these are excellent food choices for good health.

3. Lipids.
4. Vitamins.
5. Minerals.
6. Water.

Carbohydrates, proteins, and lipids give your body energy. Proteins provide building materials. Proteins, vitamins, and minerals help control body processes.

Nutrients that Provide Energy

Molecules of carbohydrates, proteins, and lipids contain energy. When your body digests food, it breaks down the molecules of these nutrients. This releases the energy so your body can use it. The energy in food is measured in units called **calories.**

Carbohydrates

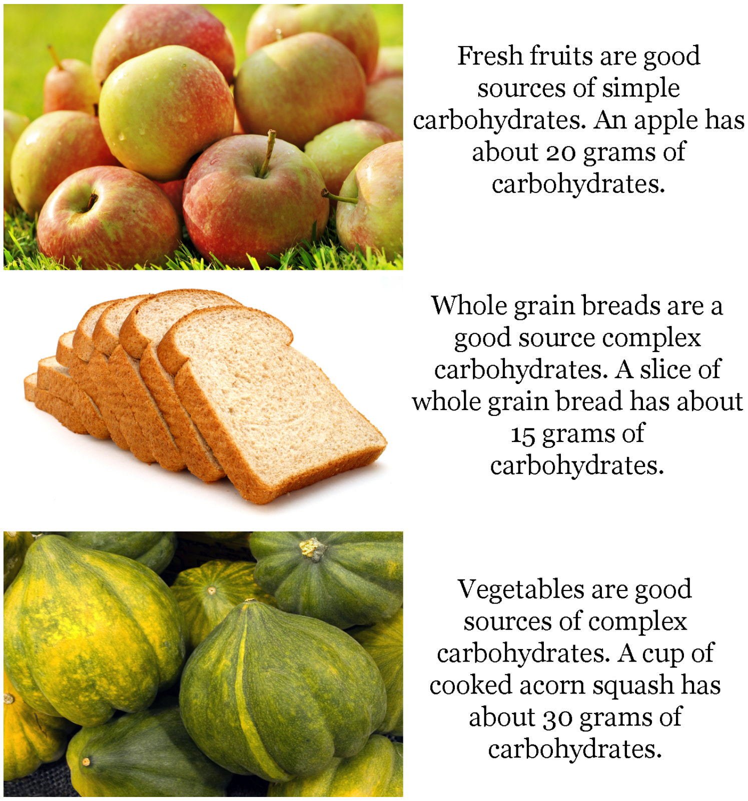
Carbohydrates are nutrients that include sugars, starches, and fiber. How many grams of carbohydrates you need each day are shown in **Figure** 6.2. It also shows some foods that are good sources of carbohydrates.

There are two types of carbohydrates: simple and complex.

Simple Carbohydrates

Sugars are small, simple carbohydrates that are found in foods such as fruits and milk. The sugar found in fruits is called fructose. The sugar found in milk is called lactose. These sugars are broken down by the body to form glucose, the simplest sugar of all. Glucose is used by cells for energy.

Remember the discussion of cellular respiration in the *Cell Functions* chapter? Cellular respiration turns glucose into the usable form of chemical energy, ATP. One gram of sugar provides your body with four



Fresh fruits are good sources of simple carbohydrates. An apple has about 20 grams of carbohydrates.

Whole grain breads are a good source complex carbohydrates. A slice of whole grain bread has about 15 grams of carbohydrates.

Vegetables are good sources of complex carbohydrates. A cup of cooked acorn squash has about 30 grams of carbohydrates.

Figure 6.2: Up to the age of 13 years, you need about 130 grams of carbohydrates a day. Most of the carbohydrates should be complex. They are broken down by the body more slowly than simple carbohydrates. Therefore, they provide energy longer and more steadily. What other foods do you think are good sources of complex carbohydrates?

Calories of energy.

Some people cannot digest lactose, the sugar in milk. This condition is called lactose intolerance. If people with this condition drink milk, they may have cramping, bloating, and gas. To avoid these symptoms, they should not drink milk, or else they should drink special, lactose-free milk.

Complex Carbohydrates

Starch is a large, complex carbohydrate. Starches are found in foods such as vegetables and grains. Starches are broken down by the body into sugars that provide energy. Like sugar, one gram of starch provides your body with four calories of energy.

Fiber is another type of large, complex carbohydrate. Unlike sugars and starches, fiber does not provide energy. However, it has other important roles in the body. There are two types of fiber found in food: soluble fiber and insoluble fiber. Each type has a different role. Soluble fiber dissolves in water. It helps keep sugar and fat at normal levels in the blood. Insoluble fiber does not dissolve in water. As it moves through the large intestine, it absorbs water. This helps keep food waste moist so it can pass easily out of the body.

Eating foods high in fiber helps fill you up without providing too many calories. Most fruits and vegetables are high in fiber. Some examples are shown in **Figure** 6.3.

Proteins

Proteins are nutrients made up of smaller molecules called amino acids. As discussed in the *Introduction to Living Things* chapter, the amino acids are arranged like ”beads on a string.” These amino acid chains then fold up into a three-dimensional molecule. Proteins have several important roles in the body. For example, proteins:

- Make up muscles.
- Help control body processes.
- Help the body fight off bacteria and other “foreign invaders.”
- Carry substances in the blood.

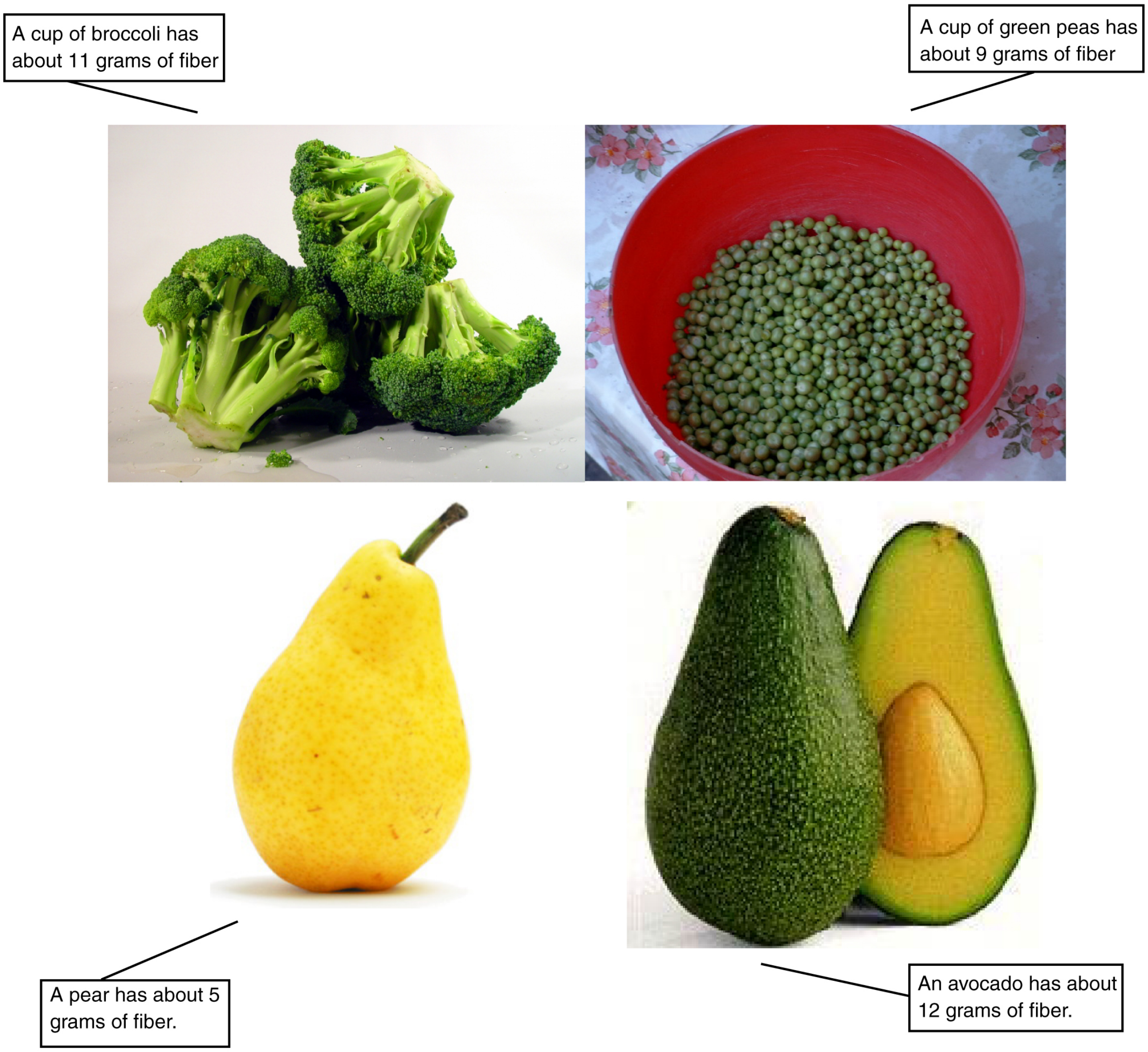
If you eat more proteins than you need for these purposes, the extra proteins are used for energy. One gram of protein provides four calories of energy. This is the same amount as one gram of sugar or starch. How many grams of proteins you need each day are shown in **Figure** 6.4. It also shows some foods that are good sources of proteins.

There are many different amino acids, the building blocks of proteins, but your body needs only 20 of them. Your body can make ten of these amino acids from simpler substances. The other ten amino acids must come from the proteins in foods. These ten are called **essential amino acids**. Only animal foods, such as milk and meat, contain all ten essential amino acids in a single food. Plant foods are missing one or more essential amino acids. However, by eating a combination of plant foods, such as beans and rice, you can get all ten essential amino acids.

Lipids

Lipids are nutrients such as fats that store energy. The heart and skeletal muscles rely mainly on lipids for energy. One gram of lipids provides nine calories of energy. This is more than twice the amount provided by carbohydrates or proteins. Lipids have several other roles in the body. For example, lipids:

High-Fiber Foods



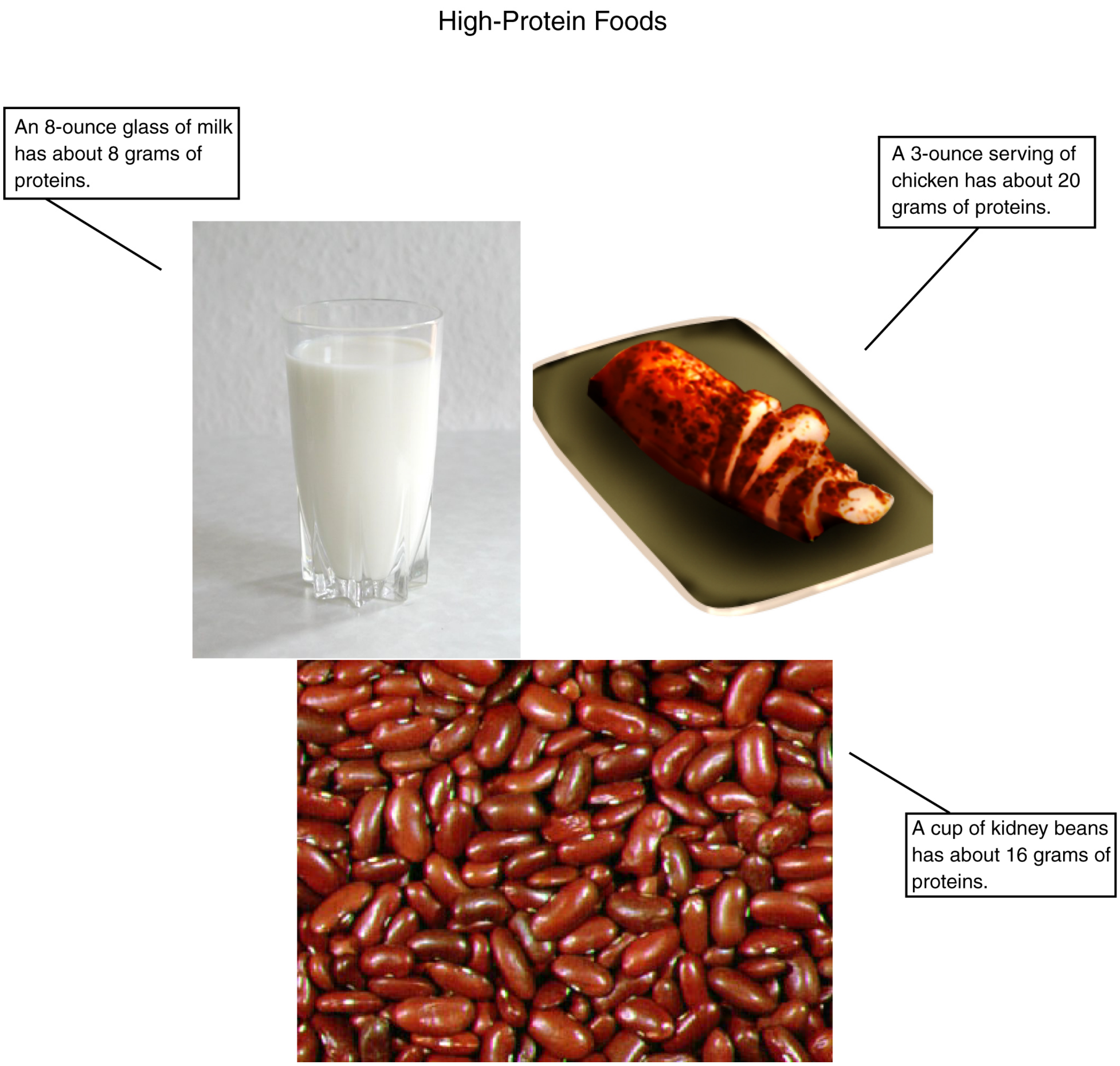
A cup of broccoli has about 11 grams of fiber

A cup of green peas has about 9 grams of fiber

A pear has about 5 grams of fiber.

An avocado has about 12 grams of fiber.

Figure 6.3: Between the ages of 9 and 13 years, girls need about 26 grams of fiber a day, and boys need about 31 grams of fiber a day. Do you know other foods that are high in fiber?



High-Protein Foods

An 8-ounce glass of milk has about 8 grams of proteins.

A 3-ounce serving of chicken has about 20 grams of proteins.

A cup of kidney beans has about 16 grams of proteins.

Figure 6.4: Between the ages of 9 and 13 years, you need about 34 grams of proteins a day. What other foods do you think are good sources of proteins?

- Protect nerves.
- Help control blood pressure.
- Help blood to clot.
- Make up the membranes that surround cells.

Fats are one type of lipid. Stored fat gives your body energy to use for later. It's like having money in a savings account. It's there in case you need it. Stored fat also cushions and protects internal organs. In addition, it insulates the body. It helps keep you warm in cold weather.

Fats and other lipids are necessary for life. However, they can be harmful if you eat too much of them, or the wrong type of fats. Fats can build up in the blood and damage blood vessels. This increases the risk of heart disease.

There are two types of lipids, saturated and unsaturated.

1. Saturated lipids can be unhealthy, even in very small amounts. They are found mainly in animal foods, such as meats, whole milk, and eggs. Saturated lipids increase cholesterol levels in the blood. Cholesterol is a fatty substance that is found naturally in the body. Too much cholesterol in the blood can lead to heart disease. It is best to limit the amount of saturated lipids in your diet.

1. Unsaturated lipids are found mainly in plant foods, such as vegetable oil, olive oil, and nuts. Unsaturated lipids are also found in fish, such as salmon. Unsaturated lipids are needed in small amounts for good health because your body cannot make them. Most lipids in your diet should be unsaturated.

Another type of lipid is called **trans fat**. Trans fats are manufactured and added to certain foods to keep them fresher for longer. Foods that contain trans fats include cakes, cookies, fried foods, and margarine. Eating foods that contain trans fats increases the risk of heart disease. You should do your best to eat fewer foods that contain it.

Beginning in 2010, California banned trans fats from restaurant products, and, beginning in 2011, from all retail baked goods.

Vitamins and Minerals

Vitamins and minerals are also nutrients. They do not provide energy, but they are needed for good health.

Vitamins

Vitamins are substances that the body needs in small amounts to function properly. Humans need 13 different vitamins. Some of them are listed in **Table** 6.1. The table also shows how much of each vitamin you need each day. Vitamins have many roles in the body. For example, Vitamin A helps maintain good vision. Vitamin B_9 helps form red blood cells. Vitamin K is needed for blood to clot when you have a cut or other wound.

Table 6.1: **Vitamins Needed For Good Health**

Vitamin	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Vitamin A	Needed for good vision	Carrots, spinach, milk, eggs	600 g (1 g = 1 x 10^{-6} g)
Vitamin B_1	Needed for healthy nerves	Whole wheat, peas, meat, beans, fish, peanuts	0.9 mg (1 mg = 1 x 10^{-3} g)
Vitamin B_3	Needed for healthy skin and nerves	Beets, liver, pork, turkey, fish, peanuts	12 mg
Vitamin B_9	Needed to make red blood cells	Liver, peas, dried beans, green leafy vegetables	300 g
Vitamin B_{12}	Needed for healthy nerves	Meat, liver, milk, shellfish, eggs	1.8 g
Vitamin C	Needed for growth and repair of tissues	Oranges, grapefruits, red peppers, broccoli	45 mg
Vitamin D	Needed for healthy bones and teeth	Milk, salmon, tuna, eggs	5 g
Vitamin K	Needed for blood to clot	Spinach, Brussels sprouts, milk, eggs	60 g

Some vitamins are produced in the body. For example, vitamin D is made in the skin when it is exposed to sunlight. Vitamins B_{12} and K are produced by bacteria that normally live inside the body. Most other vitamins must come from foods. Foods that are good sources of vitamins are listed in **Table** 6.1. They include whole grains, vegetables, fruits, and milk.

Not getting enough vitamins can cause health problems. For example, too little vitamin C causes a disease called scurvy. People with scurvy have bleeding gums, nosebleeds, and other symptoms. Getting too much of some vitamins can also cause health problems. The vitamins to watch out for are vitamins A, D, E, and K. These vitamins are stored by the body, so they can build up to high levels. Very high levels of these vitamins can even cause death, although this is very rare.

Minerals

Minerals are chemical elements that are needed for body processes. Minerals are different from vitamins because they do not contain the element carbon. Minerals that you need in relatively large amounts are listed in **Table** 6.2. Minerals that you need in smaller amounts include iodine, iron, and zinc.

Minerals have many important roles in the body. For example, calcium and phosphorus are needed for strong bones and teeth. Potassium and sodium are needed for muscles and nerves to work normally.

Table 6.2: **Minerals Needed For Good Health**

Mineral	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Calcium	Needed for strong bones and teeth	Milk, soy milk, green leafy vegetables	1,300 mg

Table 6.2: (continued)

Mineral	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Chloride	Needed for proper balance of water and salts in body	Table salt, most packaged foods	2.3 g
Magnesium	Needed for strong bones	Whole grains, green leafy vegetables, nuts	240 mg
Phosphorus	Needed for strong bones and teeth	Meat, poultry, whole grains\	1,250 mg
Potassium	Needed for muscles and nerves to work normally	Meats, grains, bananas, orange juice	4.5 g
Sodium	Needed for muscles and nerves to work normally	Table salt, most packaged foods	1.5 g

Your body cannot produce any of the minerals that it needs. Instead, you must get minerals from the foods you eat. Good sources of minerals are listed in **Table** 6.2. They include milk, green leafy vegetables, and whole grains.

Not getting enough minerals can cause health problems. For example, too little calcium may cause osteoporosis. This is a disease in which bones become soft and break easily. Getting too much of some minerals can also cause health problems. Many people get too much sodium. Sodium is added to most packaged foods. People often add more sodium to their food by using table salt. Too much sodium causes high blood pressure in some people.

Water

Did you know that water is also a nutrient? By weight, your cells are about two-thirds water, so you cannot live without it. In fact, you can survive for only a few days without water.

You lose water in each breath you exhale. You also lose water in sweat and urine. If you do not take in enough water to replace the water that you lose, you may develop dehydration. Symptoms of dehydration include dry mouth, headaches, and feeling dizzy. Dehydration can be very serious. Severe dehydration can even cause death.

When you exercise, especially on a hot day, you lose more water in sweat than you usually do. You need to drink extra water before, during, and after exercise. The children in **Figure** 6.5 are drinking water while playing outside on a warm day. They need to drink water to avoid dehydration.

Getting too much water can also be dangerous. Excessive water may cause a condition called hyponatremia. In this condition, water collects in the brain and causes it to swell. Hyponatremia can cause death. It requires emergency medical care.

Lesson Summary

- The body needs food for energy, building materials, and substances that help control body processes.
- Carbohydrates, proteins, and lipids provide energy and have other important roles in the body.
- Vitamins and minerals do not provide energy but are needed in small amounts for the body to function properly.

Figure 6.5: When you are active outside on a warm day, it's important to drink plenty of water. You need to replace the water you lose in sweat.

- The body must have water to survive.

Review Questions

Recall

1. What are three reasons that your body needs food?

2. Which nutrients can be used for energy?

3. What are some foods that are good sources of vitamin C?

4. What are two minerals that are needed for strong bones and teeth?

Apply Concepts

5. Name two types of fiber and state the role of each type of fiber in the body.

6. Your body needs 20 different amino acids. Why do you need to get only ten of these amino acids from food? Name foods you can eat to get these ten amino acids.

7. Compare and contrast saturated and unsaturated lipids.

8. Identify three vitamins that are produced in the body. How are they produced?

9. Why do you need to drink extra water when you exercise on a hot day? What might happen if you did not drink extra water?

Critical Thinking

10. List some of the functions of proteins in the body. Based on your list, predict health problems people might have if they do not get enough proteins in foods.

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- `http://en.wikipedia.org/wiki/Vitamins`
- `http://www.alexandrapoweallred.com/`

Points to Consider

Think about how you can be sure you are getting enough nutrients.

- Do you think knowing the nutrients in the foods you eat are important?
- Do you have to keep track of all the nutrients you eat, or is there an easier way to choose foods that provide the nutrients you need?

6.2 Choosing Healthy Foods

Lesson Objectives

- State how to use MyPyramid to get the proper balance of nutrients.
- Describe how to read food labels to choose foods wisely.
- Explain how to balance food with exercise.

Check Your Understanding

- What is a nutrient?
- Why do you need extra energy when you exercise?

Vocabulary

ingredient main ingredient MyPyramid
nutrition facts label obesity serving size

Introduction

Foods such as whole grain breads, fresh fruits, and fish provide nutrients you need for good health. But different foods give you different types of nutrients. You also need different amounts of each nutrient. How can you choose the right mix of foods to get the proper balance of nutrients? Two tools can help you choose foods wisely: MyPyramid and food labels.

MyPyramid

MyPyramid is a diagram that shows how much you should eat each day of foods from six different food groups. It recommends the amount of nutrients you need based on your age, your sex, and your level of activity. MyPyramid is shown in **Figure** 6.6. The six food groups in MyPyramid are:

- Grains, such as bread, rice, pasta, and cereal.
- Vegetables, such as spinach, broccoli, carrots, and sweet potatoes.
- Fruits, such as oranges, apples, bananas, and strawberries.
- Oils, such as vegetable oil, canola oil, olive oil, and peanut oil.
- Dairy, such as milk, yogurt, cottage cheese, and other cheeses.

- Meat and beans, such as chicken, fish, soybeans, and kidney beans.

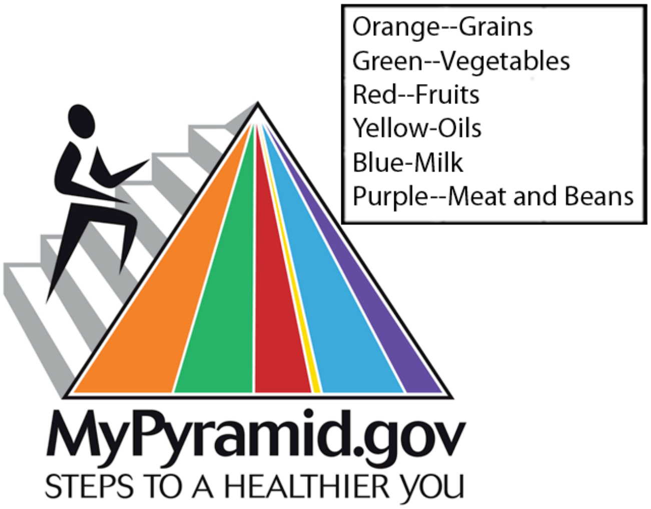


Figure 6.6: MyPyramid can help you choose foods wisely for good health. Each colored band represents a different food group. The key shows which food group each color represents. Which colored band of MyPyramid is widest? Which food group does it represent?

Using MyPyramid

In MyPyramid, each food group is represented by a band of a different color. For example, grains are represented by an orange band, and vegetables are represented by a green band. The wider the band, the more foods you should choose from that food group each day.

The orange band in MyPyramid is the widest band. This means that you should choose more foods from the grain group than from any other single food group. The green, blue, and red bands are also relatively wide. Therefore, you should choose plenty of foods from the vegetable, dairy, and fruit groups as well. You should choose the fewest foods from the food group with the narrowest band. Which band is narrowest? Which food group does it represent?

Healthy Eating Guidelines

Did you ever hear the saying, "variety is the spice of life"? Variety is also the basis of a healthy eating plan. When you choose foods based on MyPyramid, you should choose a variety of different foods. Follow these guidelines to make the wisest food choices for good health. Keep in mind that nutritional rules may change as you get older. As food provides energy and nutrients for growth and development, nutritional requirements may vary with body weight, age, sex, activity, and body functioning.

- Make at least half your daily grain choices whole grains. Examples of whole grains are whole wheat bread, whole wheat pasta, and brown rice.
- Choose a variety of different vegetables each day. Be sure to include both dark green vegetables, such as spinach and broccoli, and orange vegetables, such as carrots and sweet potatoes.

- Choose a variety of different fruits each day. Select mainly fresh fruits rather than canned fruits and whole fruits instead of fruit juices.
- When choosing oils, go for unsaturated oils, such as olive oil, canola oil, or vegetable oil.
- Choose low-fat or fat-free milk and other dairy products. For example, select fat-free yogurt and low-fat cheese.
- For meats, choose fish, chicken, and lean cuts of beef. Also, be sure to include beans, nuts, and seeds.

What about Ice Cream, Cookies, and Potato Chips?

Are you wondering where foods like ice cream, cookies, and potato chips fit into MyPyramid? The white tip of MyPyramid represents foods such as these. These are foods that should be eaten only in very small amounts and not very often. Such foods contain very few nutrients, and are called nutrient-poor. Instead, they are high in fats, sugars, and sodium, which are nutrients that you should limit in a healthy eating plan. Ice cream, cookies, and potato chips are also high in calories. Eating too much of them may lead to unhealthy weight gain.

Food Labels

In the United States, packaged foods are required by law to have nutrition facts labels. A **nutrition facts label** shows the nutrients in a food. Packaged foods are also required to list their ingredients. An **ingredient** is a specific item that a food contains.

Using Nutrition Facts Labels

An example of a nutrition facts label is shown in **Figure** 6.7. The information listed at the right of the label tells you what to look for. At the top of the label, look for the serving size. The serving size tells you how much of the food you should eat to get the nutrients listed on the label. A cup of food from the label in **Figure** 6.7 is a serving. The calories in one serving are listed next. In this food, there are 250 calories per serving.

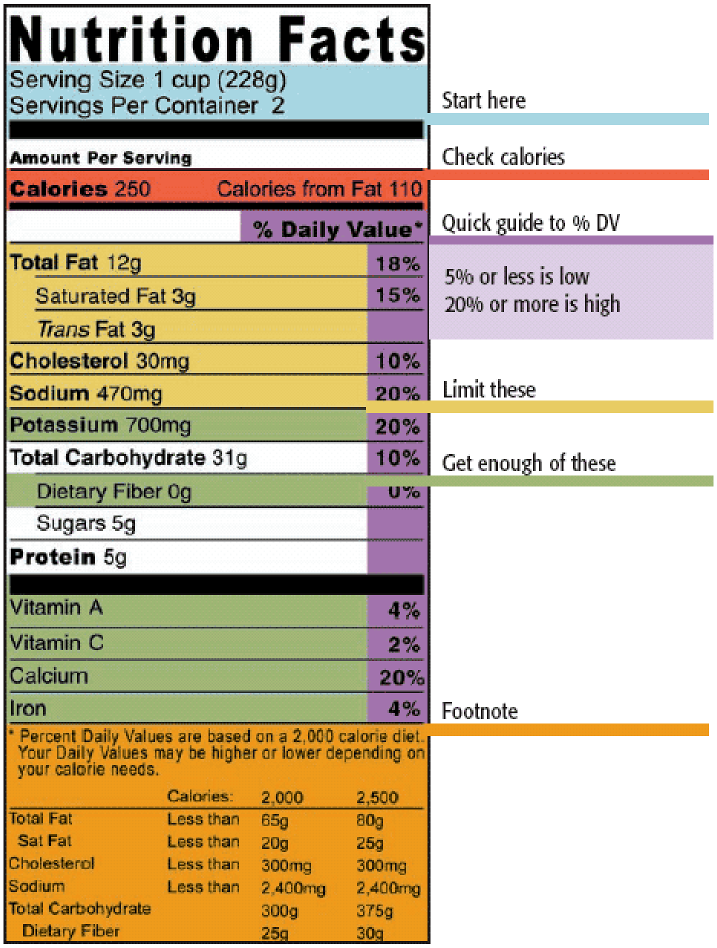
Next on the nutrition facts label, look for the percent daily values (% DV) of nutrients. Remember the following tips when reading a food label:

- A food is low in a nutrient if the percent daily value of the nutrient is 5% or less.
- The healthiest foods are low in nutrients such as fats and sodium.
- A food is high in a nutrient if the percent daily value of the nutrient is 20% or more.
- The healthiest foods are high in nutrients such as fiber and proteins.

Look at the percent daily values on the food label in **Figure** 6.7. Which nutrients have values of 5% or less? These are the nutrients that are low in this food. They include fiber, vitamin A, vitamin C, and iron. Which nutrients have values of 20% or more? These are the nutrients that are high in this food. They include sodium, potassium, and calcium.

Using Ingredients Lists

The food label in **Figure** 6.8 includes the list of ingredients in a different food. The ingredients on food labels are always listed from the highest amount to the lowest amount. This means that the main ingredient is listed first. The **main ingredient** is the ingredient that is present in the food in the greatest amount. As you go down the list, the ingredients are present in smaller and smaller amounts.



Nutrition Facts

Serving Size 1 cup (228g)
Servings Per Container 2

Amount Per Serving

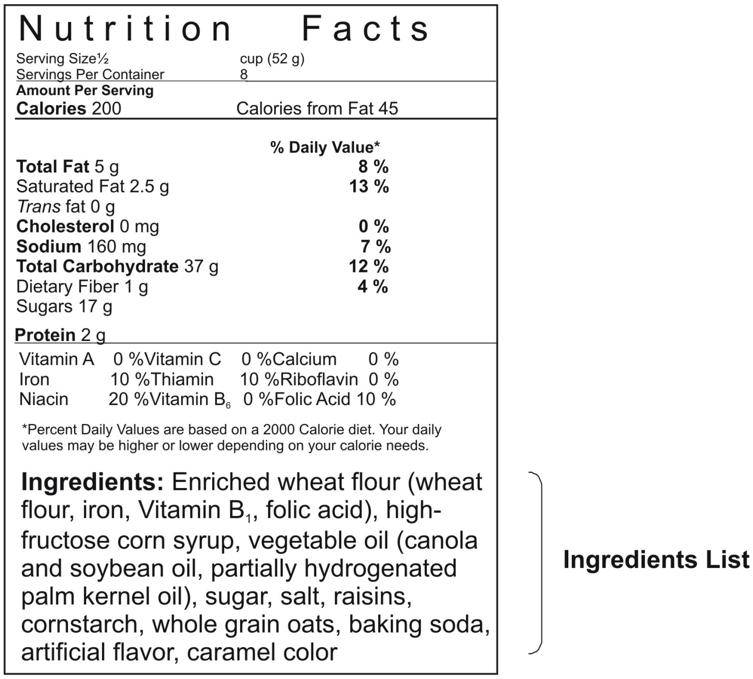
Calories 250 Calories from Fat 110

	% Daily Value*
Total Fat 12g	**18%**
Saturated Fat 3g	**15%**
Trans Fat 3g	
Cholesterol 30mg	**10%**
Sodium 470mg	**20%**
Potassium 700mg	**20%**
Total Carbohydrate 31g	**10%**
Dietary Fiber 0g	**0%**
Sugars 5g	
Protein 5g	
Vitamin A	**4%**
Vitamin C	**2%**
Calcium	**20%**
Iron	**4%**

* Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Figure 6.7: Reading nutrition facts labels can help you choose healthy foods. Look at the nutrition facts label shown here. Do you think this food is a good choice for a healthy eating plan? Why or why not?



Nutrition Facts

Serving Size½ cup (52 g)
Servings Per Container 8

Amount Per Serving
Calories 200 Calories from Fat 45

	% Daily Value*
Total Fat 5 g	**8 %**
Saturated Fat 2.5 g	**13 %**
Trans fat 0 g	
Cholesterol 0 mg	**0 %**
Sodium 160 mg	**7 %**
Total Carbohydrate 37 g	**12 %**
Dietary Fiber 1 g	**4 %**
Sugars 17 g	
Protein 2 g	

Vitamin A	0 %	Vitamin C	0 %	Calcium	0 %
Iron	10 %	Thiamin	10 %	Riboflavin	0 %
Niacin	20 %	Vitamin B_6	0 %	Folic Acid	10 %

*Percent Daily Values are based on a 2000 Calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Enriched wheat flour (wheat flour, iron, Vitamin B_1, folic acid), high-fructose corn syrup, vegetable oil (canola and soybean oil, partially hydrogenated palm kernel oil), sugar, salt, raisins, cornstarch, whole grain oats, baking soda, artificial flavor, caramel color

Figure 6.8: This food label includes the list of ingredients in the food. The main ingredient is enriched wheat flour, followed by high-fructose corn syrup. Why should you avoid foods with ingredients such as these at the top of the ingredients list?

Reading the ingredients lists on food labels can help you choose the healthiest foods. At the top of the list, look for ingredients such as whole grains, vegetables, milk, and fruits. These are the ingredients you need in the greatest amounts for balanced eating. Avoid foods that list fats, oils, sugar, or salt at the top of the list. For good health, you should avoid getting too much of these ingredients. Be aware that ingredients such as corn syrup are sugars.

You should also use moderation when eating foods that contain ingredients such as white flour or white rice. These ingredients have been processed, and processing removes nutrients. The word ”enriched” is a clue that an ingredient has been processed. Ingredients are enriched with added nutrients to replace those lost during processing. However, enriched ingredients are still likely to have fewer nutrients than unprocessed ingredients.

Balancing Food with Exercise

Look at MyPyramid in **Figure** 6.6. Note the person walking up the side of the pyramid. This shows that exercise is important for balanced eating. Exercise helps you use any extra energy in the foods you eat. The more active you are, the more energy you use. You should try to get at least an hour of physical activity just about every day. **Figure** 6.9 shows some activities that can help you use extra energy.

How Does Fat Form?

Any unused energy in food is stored in the body as fat. This is true whether the extra energy comes from carbohydrates, proteins, or lipids. What happens if you take in more energy than you use, day after day? You will store more and more fat and become overweight.

Eventually, you may become obese. **Obesity** is having a very high percentage of body fat. Obese people

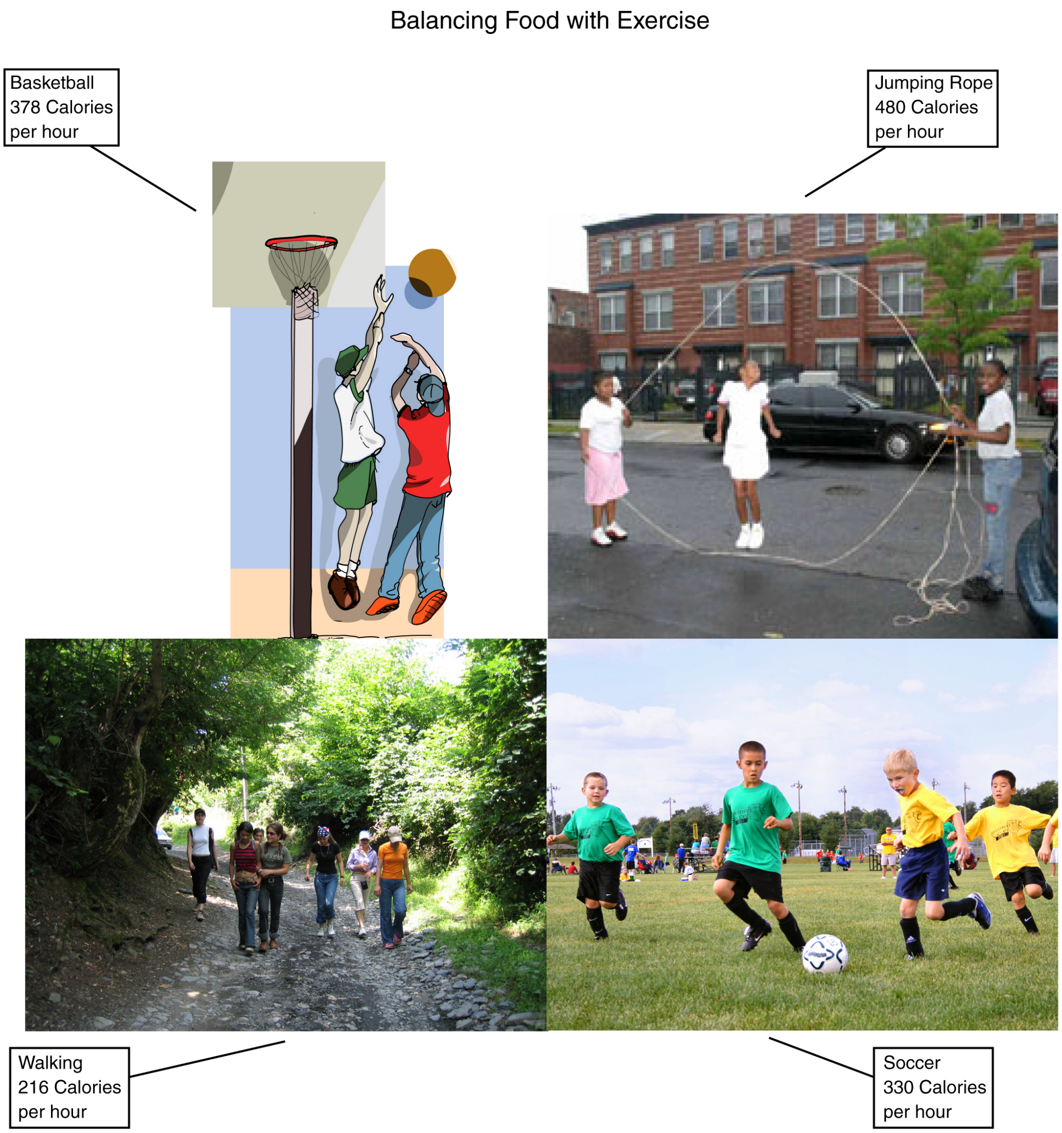

Balancing Food with Exercise
Basketball 378 Calories per hour
Jumping Rope 480 Calories per hour
Walking 216 Calories per hour
Soccer 330 Calories per hour

Figure 6.9: All of these activities are good ways to exercise and use extra energy. The calories given for each activity are the number of calories used in an hour by a person that weighs 100 pounds. Which of these activities uses the most calories? Which of the activities do you enjoy?

are at least 20 percent heavier than their healthy weight range. The excess body fat of obesity is linked to many diseases. Obese people often have serious health problems, such as diabetes, high blood pressure, and high cholesterol. They are also more likely to develop arthritis and some types of cancer. People that remain obese during their entire adulthood usually do not live as long as people that stay within a healthy weight range.

The current generation of children and teens is the first generation in our history that may have a shorter life than their parents. The reason is their high rate of obesity and the health problems associated with obesity. You can avoid gaining weight and becoming obese. The choice is yours. Choose healthy foods by using MyPyramid and reading food labels. Then get plenty of exercise to balance the energy in the foods you eat.

Lesson Summary

- MyPyramid shows how much you should eat each day of foods from six different food groups.
- Reading food labels can help you choose the healthiest foods.
- Regular exercise helps you use extra energy and avoid unhealthy weight gain.

Review Questions

Recall

1. List the six food groups represented by MyPyramid.

2. Which food group contains soybeans, kidney beans, and fish?

3. What guideline should you follow in choosing foods from the grains food group?

4. Which ingredient is always listed first on a food label?

5. What happens if you take in more energy than you use, day after day?

Apply Concepts

6. Explain how you can use MyPyramid to choose foods that provide the proper balance of nutrients.

7. Why should you limit foods like ice cream and potato chips in a healthy eating plan?

8. Explain how you can use food labels to choose foods that are high in fiber.

9. Why should you try to avoid foods with processed ingredients? What are some examples of processed ingredients?

Critical Thinking

10. You are trying to convince your friends that it is worth it to eat healthy and do physical activity. What will you tell them? Give examples from the chapter.

Further Reading / Supplemental Links

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- `http://www.cfsan.fda.gov/~dms/foodlab.html`
- `http://www.fns.usda.gov/tn/parents/nutritionlabel.html`
- `http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf`
- `http://www.mypyramid.gov`
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Points to Consider

Next we discuss the digestive system.

- Discuss how you think foods may be broken down into nutrients that your body can use? For example, how do you think an apple becomes simple sugars that your body can use for energy? Or how might a piece of cheese become proteins that your body can use for building materials?

6.3 The Digestive System

Lesson Objectives

- List the functions of the digestive system.
- Explain the role of enzymes in digestion.
- Describe the digestive organs and their functions.
- Explain the roles of helpful bacteria in the digestive system.
- List ways to help keep your digestive system healthy.

Check Your Understanding

- What is a chemical reaction?
- What is an enzyme?
- What are bacteria?

Vocabulary

absorption chemical digestion digestion
digestive system duodenum esophagus
food allergies ileum jejunum
large intestine mechanical digestion small intestine
stomach villi

What Does the Digestive System Do?

Nutrients in the foods you eat are needed by the cells of your body. How do the nutrients in foods get to your body cells? What organs and processes break down the foods and make the nutrients available to cells? The organs are those of the digestive system. The processes are digestion and absorption.

The **digestive system** is the body system that breaks down food and absorbs nutrients. It also gets rid of solid food waste. The main organs of the digestive system are shown in **Figure** 6.10.

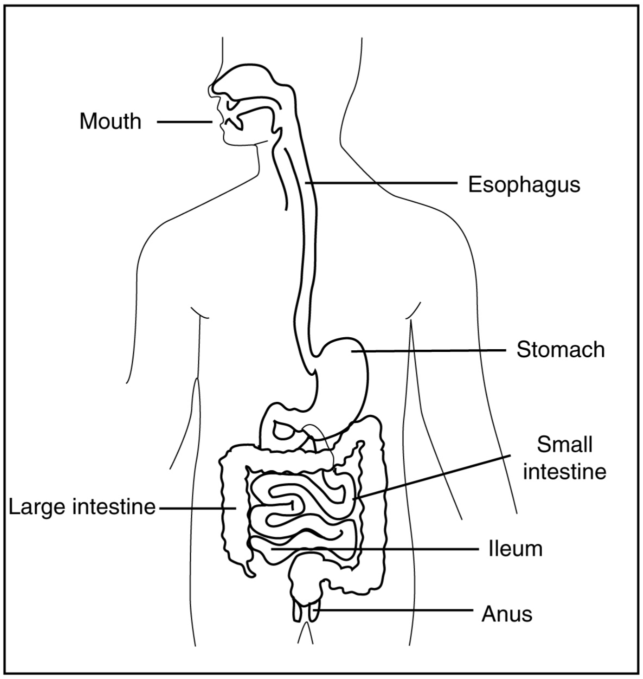

Figure 6.10: This drawing shows the major organs of the digestive system. Trace the path of food through the organs of the digestive system as you read about them in this lesson.

Digestion is the process of breaking down food into nutrients. There are two types of digestion, mechanical and chemical. In **mechanical digestion**, large chunks of food are broken down into small pieces. This is a physical process. In **chemical digestion**, large food molecules are broken down into small nutrient molecules. This is a chemical process.

Absorption is the process that allows substances you eat to be taken up by the blood. After food is broken down into small nutrient molecules, the molecules are absorbed by the blood. After absorption, the nutrient molecules travel in the bloodstream to cells throughout the body.

Some substances in food cannot be broken down into nutrients. They remain behind in the digestive system after the nutrients are absorbed. Any substances in food that cannot be digested and absorbed pass out of the body as solid waste. The process of passing solid food waste out of the body is called elimination.

The Role of Enzymes in Digestion

Chemical digestion could not take place without the help of digestive enzymes. An **enzyme** is a protein that speeds up chemical reactions in the body. Digestive enzymes speed up chemical reactions that break down large food molecules into small molecules.

Did you ever use a wrench to tighten a bolt? You could tighten a bolt with your fingers, but it would be difficult and slow. If you use a wrench, you can tighten a bolt much more easily and quickly. Enzymes are like wrenches. They make it much easier and quicker for chemical reactions to take place. Like a wrench, enzymes can also be used over and over again. But you need the appropriate size and shape of the wrench to efficiently tighten the bolt, just like each enzyme is specific for the reaction it helps.

Digestive enzymes are released, or secreted, by the organs of the digestive system. Examples of digestive enzymes are:

- Amylase, produced in the mouth. It helps break down large starches molecules into smaller sugar molecules.
- Pepsin, produced in the stomach. Pepsin helps break down proteins into amino acids.
- Trypsin, produced in the pancreas. Trypsin also breaks down proteins.
- Pancreatic lipase, produced in the pancreas. It is used to break apart fats.
- Deoxyribonuclease and ribonuclease, produced in the pancreas. They are enzymes that break bonds in nucleic acids like DNA and RNA.

Bile salts are bile acids that help to break down fat. Bile acids are made in the liver. When you eat a meal, bile is secreted into the intestine, where it breaks down the fats. Bile acids also help to remove cholesterol from the body.

Hormones and Digestion

If you are a typical teenager, you like to eat. For your body to break down, absorb and spread the nutrients throughout your body, your digestive system and endocrine system need to work together. The endocrine system sends hormones around your body to communicate between cells like chemical messengers.

Digestive hormones are made by cells lining the stomach and small intestine. These hormones cross into the blood where they can affect other parts of the digestive system. Some of these hormones are listed below.

- Gastrin, which signals the secretion of gastric acid.
- Cholecystokinin, which signals the secretion of pancreatic enzymes.
- Secretin, which signals secretion of water and bicarbonate from the pancreas.
- Ghrelin, which signals when you are hungry.
- Gastric inhibitory polypeptide, which stops or decreases gastric secretion. It also causes the release of insulin in response to high blood glucose levels.

Digestive Organs and Their Roles

The mouth and stomach are just two of the organs of the digestive system. Other digestive system organs are the esophagus, small intestine, and large intestine. From **Figure 17.10** you can see that the digestive organs form a long tube. In adults, this tube is about 30 feet long! At one end of the tube is the mouth. At the other end is the anus. Food enters the mouth and then passes through the rest of the digestive system. Food waste leaves the body through the anus.

The organs of the digestive system are lined with muscles. The muscles contract, or tighten, to push food through the system. This is shown in **Figure** 6.11. The muscles contract in waves. The waves pass through the digestive system like waves through a slinky. This movement of muscle contractions is called peristalsis. Without peristalsis, food would not be able to move through the digestive system. Peristalsis is an involuntary process, which means that it occurs without your conscious control.

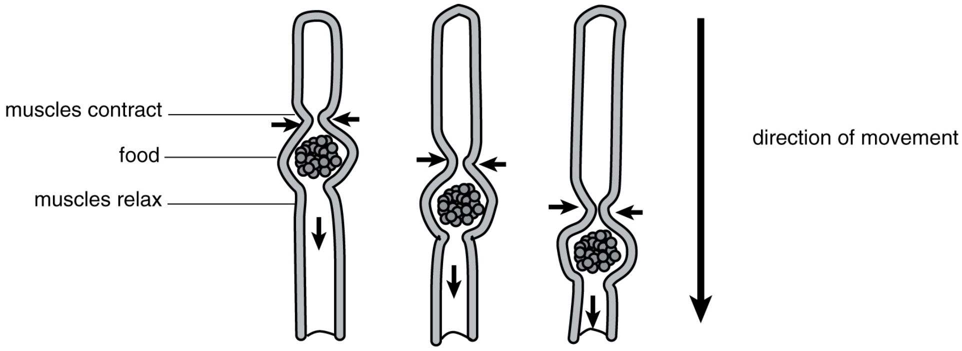

Figure 6.11: This diagram shows how muscles push food through the digestive system. Muscle contractions travel through the system in waves, pushing the food ahead of them. This is called peristalsis.

The liver, gall bladder, and pancreas are also organs of the digestive system. They are shown in **Figure** 6.12. Food does not pass through these three organs. However, these organs are important for digestion. They secrete or store enzymes or other chemicals that are needed to help digest food chemically.

Mouth, Esophagus, and Stomach

The mouth is the first organ that food enters. But digestion may start even before you put the first bite of food into your mouth. Just seeing or smelling food can cause the release of saliva and digestive enzymes in your mouth.

Once you start eating, saliva wets the food, which makes it easier to break up and swallow. Digestive enzymes, including amylase, start breaking down starches into sugars. Your tongue helps mix the food with the saliva and enzymes.

Your teeth also help digest food. Your front teeth are sharp. They cut and tear food when you bite into it. Your back teeth are broad and flat. They grind food into smaller pieces when you chew. Chewing is part of mechanical digestion. Your tongue pushes the food to the back of your mouth so you can swallow it. When you swallow, the lump of chewed food passes down your throat to your esophagus.

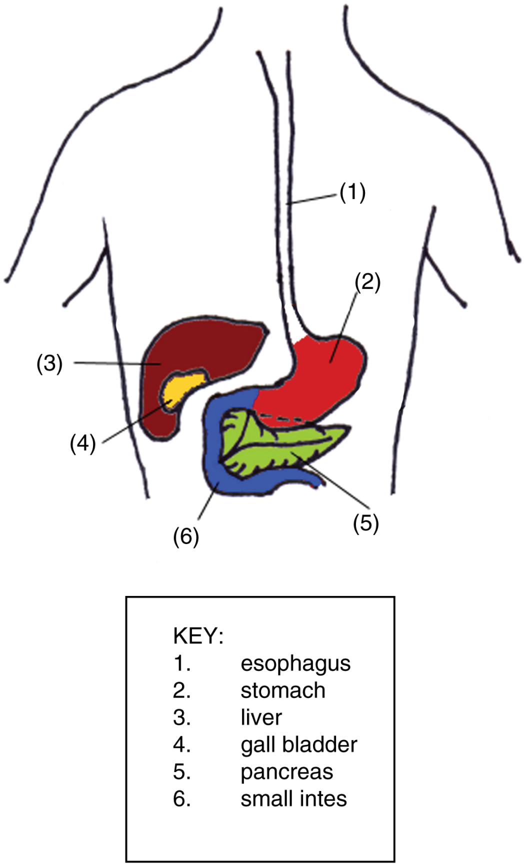

Figure 6.12: This drawing shows the liver, gall bladder, and pancreas. These organs are part of the digestive system. Food does not pass through them, but they secrete substances needed for chemical digestion.

The **esophagus** is a narrow tube that carries food from the throat to the stomach. Food moves through the esophagus because of peristalsis. At the lower end of the esophagus, a circular muscle controls the opening to the stomach. The muscle relaxes to let food pass into the stomach. Then the muscle contracts again to prevent food from passing back into the esophagus.

Some people think that gravity moves food through the esophagus. If that were true, food would move through the esophagus only when you are sitting or standing upright. In fact, because of peristalsis, food can move through the esophagus no matter what position you are in — even upside down! Just don't try to swallow food when you upside down! You could choke if you try to swallow when you are not upright.

The **stomach** is a sac-like organ at the end of the esophagus. It has thick muscular walls. The muscles contract and relax. This moves the food around and helps break it into smaller pieces. Mixing the food around with the enzyme pepsin and other chemicals helps digest proteins.

Water, salt, and simple sugars can be absorbed into the blood from the stomach. Most other substances are broken down further in the small intestine before they are absorbed. The stomach stores food until the small intestine is ready to receive it. A circular muscle controls the opening between the stomach and small intestine. When the small intestine is empty, the muscle relaxes. This lets food pass from the stomach into the small intestine.

Small Intestine

The **small intestine** is narrow tube that starts at the stomach and ends at the large intestine (see **Figure** 6.10). In adults, the small intestine is about 23 feet long. It is made up of three parts, the duodenum, the jejunum and the ileum.

1. The **duodenum** is the first part of the small intestine. This is where most chemical digestion takes place. Many enzymes and other chemicals are secreted here.
2. The **jejunum** is the second part of the small intestine. This is where most nutrients are absorbed into the blood. The jejunum is lined with tiny "fingers" called **villi**. A magnified picture of villi is shown in **Figure** 6.13. Villi contain very tiny blood vessels. Nutrients are absorbed into the blood through these tiny vessels. There are millions of villi, so altogether there is a very large area for absorption to take place. In fact, villi make the inner surface area of the small intestine 1,000 times larger than it would be without them. The entire inner surface area of the small intestine is about as big as a basketball court!
3. The **ileum** is the third part of the small intestine. Like the jejunum, the ileum is covered with villi. A few remaining nutrients are absorbed in the ileum. From the ileum, any remaining food waste passes into the large intestine.

The small intestine is much longer than the large intestine. So why is it called "small"? If you compare the small and large intestines in **Figure** 6.10, you will see why. The small intestine is smaller in width than the large intestine.

Large Intestine

The **large intestine** is a wide tube that connects the small intestine with the anus. In adults, it is about 5 feet long. Waste enters the large intestine from the small intestine in a liquid state. As the waste moves through the large intestine, excess water is absorbed from it. After the excess water is absorbed, the remaining solid waste is called feces.

Circular muscles control the anus. They relax to let the feces pass out of the body through the anus. After

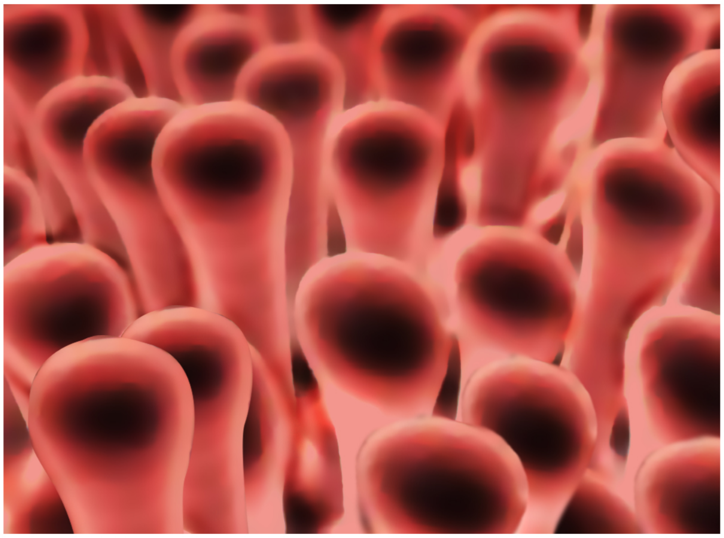

Figure 6.13: This is what the villi lining the small intestine look like when magnified. Each one is actually only about 1 millimeter long. Villi are just barely visible with the unaided eye.

feces pass out of the body, they are called stool. Releasing the stool from the body is referred to as a bowel movement.

Liver

The liver has a wide range of functions, a few of which are:

- Removing toxins from the blood.
- Keeping glucose levels stable.
- Creating proteins.
- Producing biochemicals for digestion.

The liver is necessary for survival. You cannot live without a liver. The liver is one of the most important organs in the body when it comes to getting rid of toxins, especially from the gut. The liver filters blood from the intestine. This filtering process can remove microorganisms such as bacteria, fungi, viruses and parasites from the blood. Almost 2 quarts of blood pass through the liver every minute. Since the liver also ensures that glucose levels remain stable, people with liver problems are at risk for diabetes.

Bacteria in the Digestive System

Your large intestine is not just made up of cells. It is also an ecosystem, home to trillions of bacteria. But don't worry. Most of these bacteria are helpful. They have several roles in the body. For example, intestinal bacteria:

- Produce vitamins B_{12} and K.
- Control the growth of harmful bacteria.
- Break down poisons in the large intestine.
- Break down some substances in food that cannot be digested, such as fiber and some starches and sugars.

Keeping Your Digestive System Healthy

Most of the time, you probably aren't aware of your digestive system. It works well without causing any problems. But most people have problems with their digestive system at least once in awhile. Did you ever eat something that didn't "agree" with you? Maybe you had a stomachache or felt sick to your stomach? Maybe you had diarrhea? These could be symptoms of foodborne illness.

Foodborne Illness

Harmful bacteria can enter your digestive system in food and make you sick. This is called foodborne illness. The bacteria, or the toxins they produce, may cause vomiting or cramping, in addition to the symptoms mentioned above. You can help prevent foodborne illness by following a few simple rules.

- Keep hot foods hot and cold foods cold. This helps prevent any bacteria in the foods from multiplying.
- Wash your hands before you prepare or eat food. This helps prevent bacteria on your hands from getting on the food.
- Wash your hands after you touch raw foods such as meats, poultry, fish, or eggs. These foods often contain bacteria that your hands could transfer to your mouth.
- Cook meats, poultry, fish, and eggs thoroughly before eating them. The heat of cooking kills any bacteria the foods may contain, so they cannot make you sick.

Food Allergies

Food allergies are like other allergies. They occur when the immune system reacts to harmless substances as though they were harmful. Almost 10 percent of children have food allergies. Some of the foods most likely to cause allergies are shown in **Figure** 6.14.

Eating foods you are allergic to may cause vomiting, diarrhea, or skin rashes. Some people are very allergic to certain foods. Eating even tiny amounts of the foods causes them to have serious symptoms, such as difficulty breathing. If they eat the foods by accident, they may need emergency medical treatment.

If you think you may have food allergies, a doctor can test you to find out for sure. The tests will identify which foods you are allergic to. Then you can avoid eating these foods. This is the best way to prevent the symptoms of food allergies. To avoid the foods you are allergic to, you may have to read food labels carefully. This is especially likely if you are allergic to common food ingredients, such as soybeans, wheat, or peanuts.

A food intolerance, or food sensitivity, is different from a food allergy. A food intolerance happens when the digestive system is unable to break down a certain type of food. This can result in stomach cramping, diarrhea, tiredness, and weight loss. Food intolerances are often mistakenly called allergies. Lactose intolerance is a food intolerance. A person who is lactose intolerant does not make enough lactase, the enzyme that breaks down the milk sugar lactose. About 75 percent of the world's population is lactose intolerant.

Lesson Summary

- The digestive system breaks down food, absorbs nutrients, and gets rid of food wastes.
- Digestive enzymes speed up the reactions of chemical digestion.
- The main organs of the digestive system are the mouth, esophagus, stomach, small intestine, and large intestine.
- Bacteria in the large intestine produce vitamins and have other roles in the body.

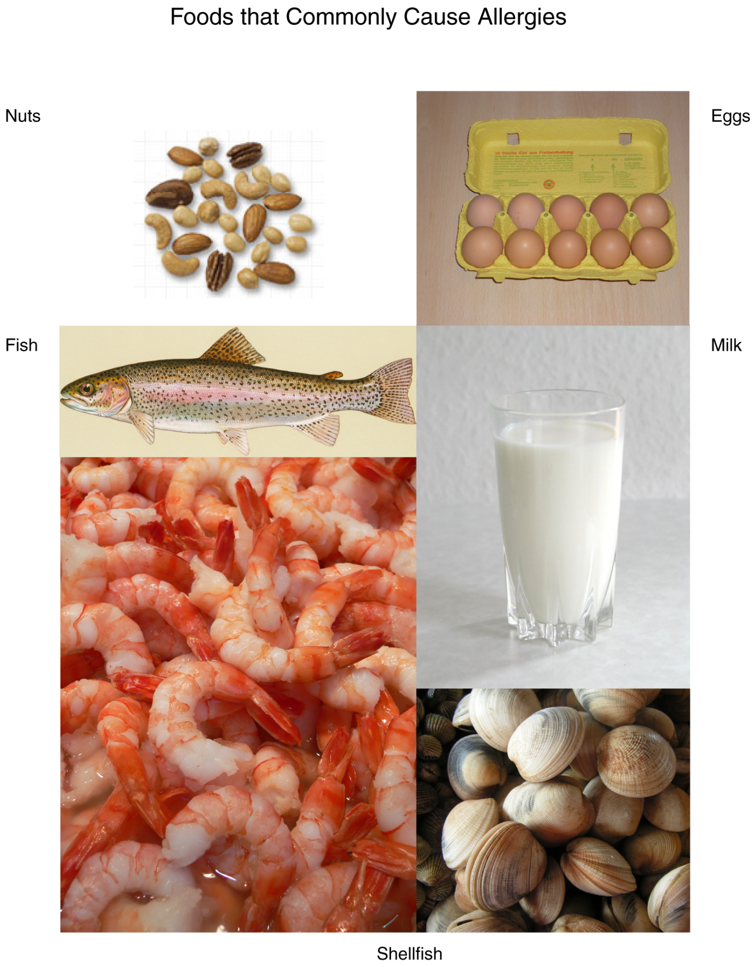

Figure 6.14: Some of the foods that commonly cause allergies are shown here. They include nuts, eggs, fish, milk, and shellfish. Are you allergic to any of these foods?

Review Questions

Recall

1. What are three functions of the digestive system?

2. Identify two roles of helpful bacteria in the large intestine.

3. List two rules that can help prevent foodborne illness.

Apply Concepts

4. Describe the roles of the mouth in digestion.

5. In which organs of the digestive system does absorption of nutrients take place? |

6. Explain the role of enzymes in digestion. Give examples to illustrate your answer.

7. Describe peristalsis, and explain why it is necessary for digestion.

8. How can the inner surface area of the small intestine be as big as a basketball court? How does this help the small intestine absorb nutrients?

Critical Thinking

9. Assume a person has an illness that prevents the large intestine from doing its normal job. Why might the person have diarrhea?

10. Explain why eating high-fiber foods can help prevent constipation.

Further Reading / Supplemental Links

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- `http://www.textbookofbacteriology.net/normalflora.html`
- `http://en.wikipedia.org/wiki/Stomach`

Points to Consider

- After nutrients are absorbed into the blood, think about how the blood could carry them to all the cells of the body. How does the blood travel? What keeps the blood moving?

Image Sources

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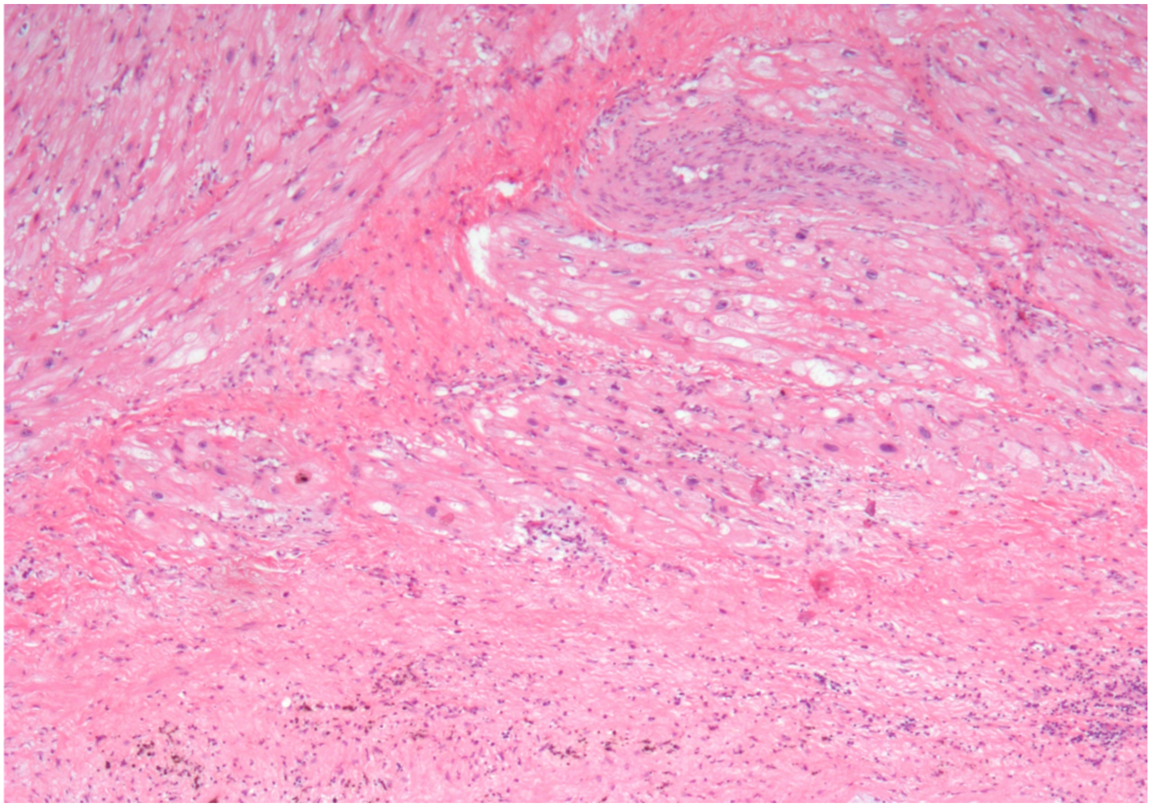
Chapter 7

MS Cardiovascular System



What does the above image show? It could be any of a number of things. A bowl of melted strawberry ice cream. Some chewed bubble gum. But the above image is actually a close-up of cardiac muscle, the muscle that makes up your heart. If you recall, cardiac muscle is one of three muscle types in the human body. Is cardiac muscle found anywhere else in the body? No. Cardiac muscle is only found in the heart!

Why is cardiac muscle only found in the heart? Why does the heart need its own special muscle? What does blood do, anyway? If a heart pumps blood, how does the heart get the blood it needs to keep pumping? What happens if the heart does not get enough blood?

You may have heard of a heart attack - but what is actually happening in the heart when that happens?

Consider these questions about the heart and cardiac muscle as you read about one of the most important and intriguing systems in the body, the cardiovascular system.

7.1 Introduction to the Cardiovascular System

Lesson Objectives

- Identify the main structures of the cardiovascular system.
- Identify three types of blood vessels.
- Describe the differences between the pulmonary and the systemic circulations.
- Identify the main structures of the lymphatic system.
- Outline how the cardiovascular and the lymphatic systems work together.

Check Your Understanding

- What is an organ system?
- What are the three types of muscles found in the human body?

Vocabulary

arteries blood capillaries
lymphatic system plasma pulmonary circulation
systemic circulation veins

Functions of the Cardiovascular System

Your cardiovascular system has many jobs. It acts as a message delivery service, a pump, a heating system, and a protector of the body against diseases. Every cell in your body depends on your cardiovascular system. In this chapter, you will learn how your cardiovascular system works and how it helps to maintain homeostasis.

The cardiovascular system shown in **Figure** 7.1 is the organ system that is made up of the heart, the blood vessels, and the blood. It moves nutrients, hormones, gases (such as oxygen) and wastes (such as carbon dioxide) to and from your cells. It also helps to keep you warm by moving warm blood around your body. To do these tasks, your cardiovascular system works with other organ systems, such as the respiratory, endocrine, and nervous systems.

The Movement of Gases

The movement of gases, especially oxygen and carbon dioxide, is one of the most important jobs of the cardiovascular system. But the cardiovascular system cannot do this alone. It must work with other organ systems, especially the respiratory system, to move these gases throughout your body.

Oxygen is needed by every cell in your body. You breathe in oxygen and breathe out carbon dioxide through your respiratory system. Once oxygen enters your lungs, it must enter your blood stream in order to move around your body. Oxygen is moved in your blood by attaching to a protein called **hemoglobin**. The oxygen moves from the blood into the tissues, while carbon dioxide travels in the opposite direction. Carbon dioxide is transported back to the lungs, where it moves out of the blood and into your lungs for release from your body.

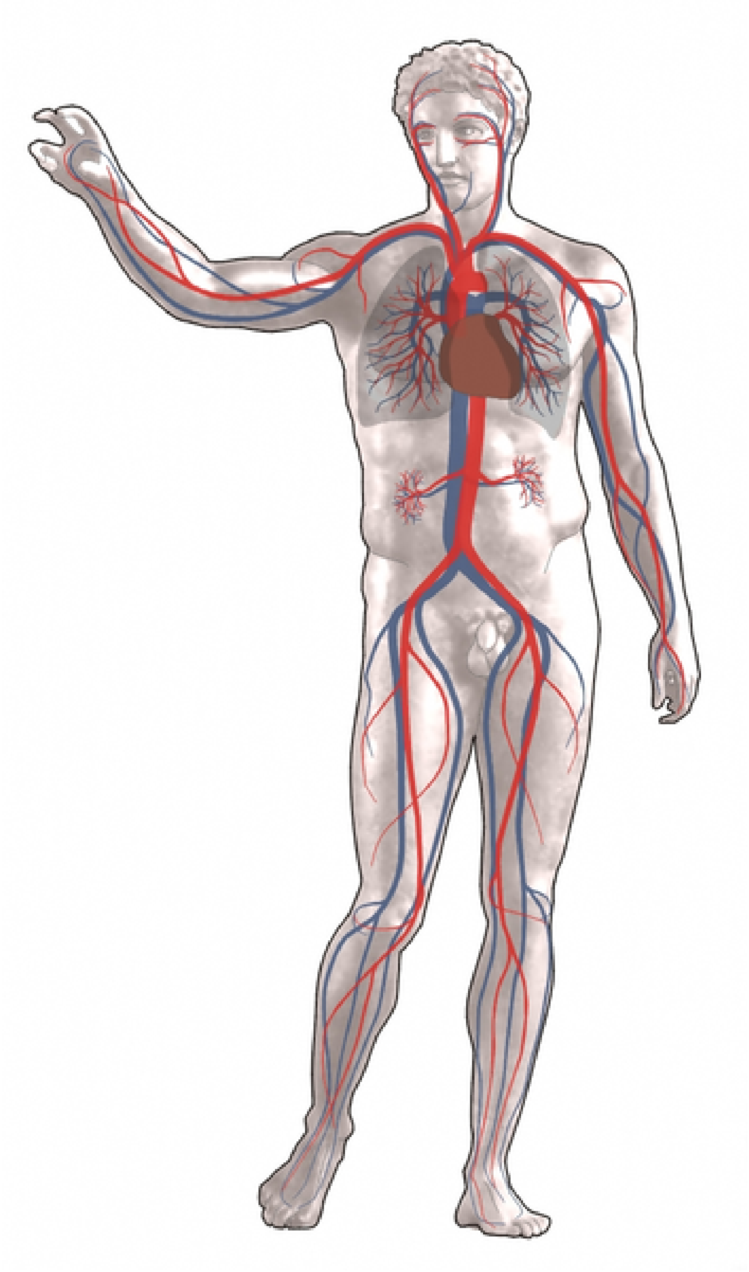


Figure 7.1: The cardiovascular system moves nutrients and other substances throughout the body.

Parts of the Cardiovascular System

Your heart pushes the blood around your body through the blood vessels. The heart, shown in **Figure** 7.2, is made of cardiac muscle. The heart is connected to many blood vessels that bring blood all around the body. The cardiac muscle contracts and pumps blood through the blood vessels.

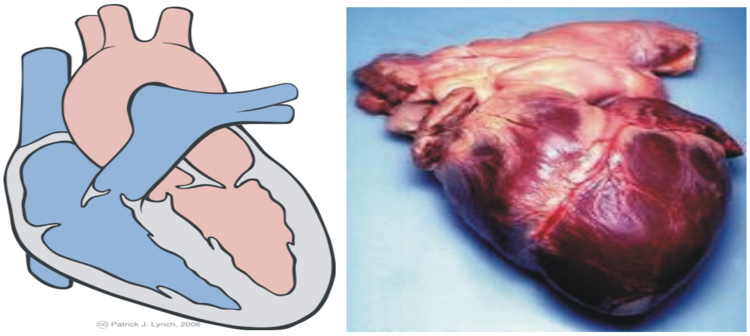


Figure 7.2: Blood is collected in the heart and pumped out to the lungs, where it releases carbon dioxide and picks up oxygen before it is pumped to the rest of the body.

Blood Vessels

The job of the blood vessels is to move the blood around the body. There are three main types of blood vessels in the body.

1. **Arteries** are blood vessels that carry blood *away* from the heart. Arteries have thick walls that have a layer of smooth muscle, as shown in **Figure** 7.3. Arteries usually carry oxygen-rich blood around the body. The blood that is in arteries is under pressure. The contractions of the heart muscle causes blood to push against the walls of the arteries. This ”push” is referred to as **blood pressure**. Blood pressure is highest in the arteries and decreases as the blood moves into smaller blood vessels. Thick walls help prevent arteries from bursting under the pressure of blood.
2. **Veins** are blood vessels that carry blood back *to* the heart. Veins have thinner walls than arteries do, as you can see in **Figure** 7.4. The blood in veins is not under pressure. Veins have valves that stop blood from moving backward. Blood is moved forward in veins when the skeletal muscles squeeze the veins. Blood that is carried by veins is usually low in oxygen. The only veins that carry oxygen-rich blood are called the pulmonary veins, which carry blood to the heart from the lungs.
3. **Capillaries** these are the tiniest blood vessels in the body. Every cell in the body needs oxygen, but arteries are too large to bring oxygen and nutrients to single cells. Further from the heart, arteries form capillaries. The walls of capillaries are only as thick as a single layer of cells. Capillaries connect arteries and veins together, as shown in **Figure** 7.5. Capillaries also send water, oxygen and other substances to body cells, while they collect carbon dioxide and other wastes from cells and tissues. Capillaries are so narrow that blood cells must move in single file through them. A capillary bed is the network of capillaries that supply an organ with blood. The more active a tissue or organ is, the more capillaries it needs to get nutrients and oxygen.

Blood

Blood is a body fluid that is a type of connective tissue. Blood is made of blood cells, and a liquid called **plasma**. The main types of cells found in blood are red blood cells and white blood cells.

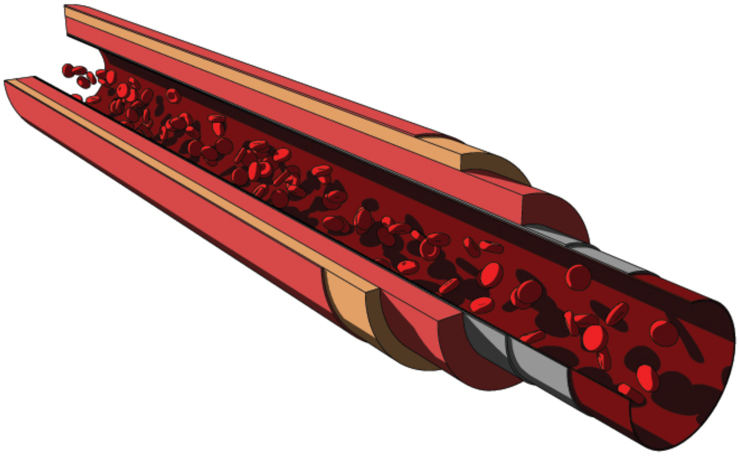


Figure 7.3: Arteries are thick-walled vessels with many layers, including a layer of smooth muscle.

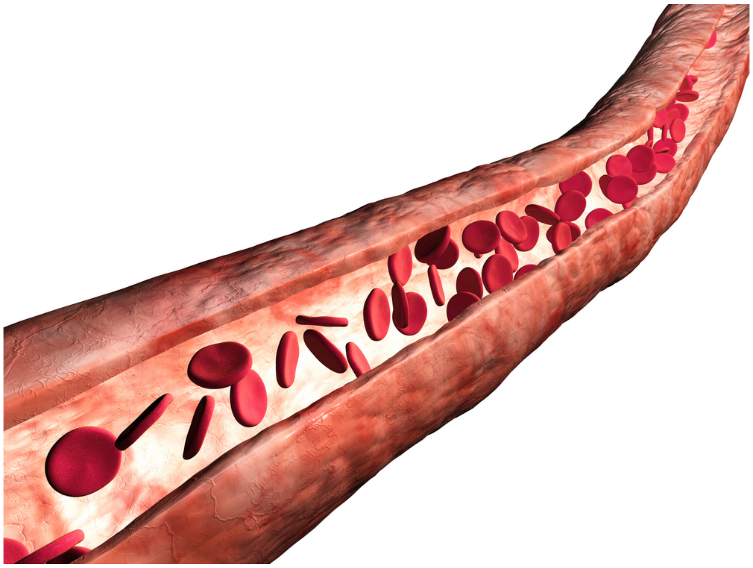


Figure 7.4: The walls of veins are not as thick as artery walls; veins have valves that stop blood from flowing backward.

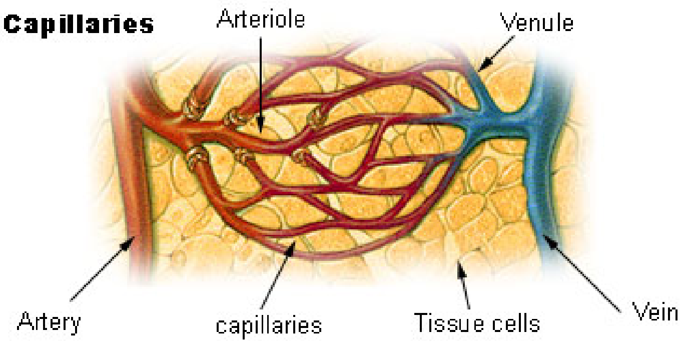


Figure 7.5: Capillaries connect arteries and veins.

- **Red blood cells** carry oxygen. Oxygen-rich blood is bright red and oxygen-poor blood is dark red.
- **White blood cells** fight against infection and disease.

The cardiovascular system of humans is ”closed.” That means the blood never leaves the blood vessels inside of the body Other organisms have blood vessels that interact with the environment.

Two Blood Circulation Systems

The blood is pumped around in two large “loops” within the body. One loop moves blood around the body - to the head, limbs, and internal organs. The other loop moves blood to and from the lungs where carbon dioxide is released and oxygen is picked up by the blood. A simple version of these two “loops” is shown in **Figure** 7.6.

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. **Pulmonary circulation** is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

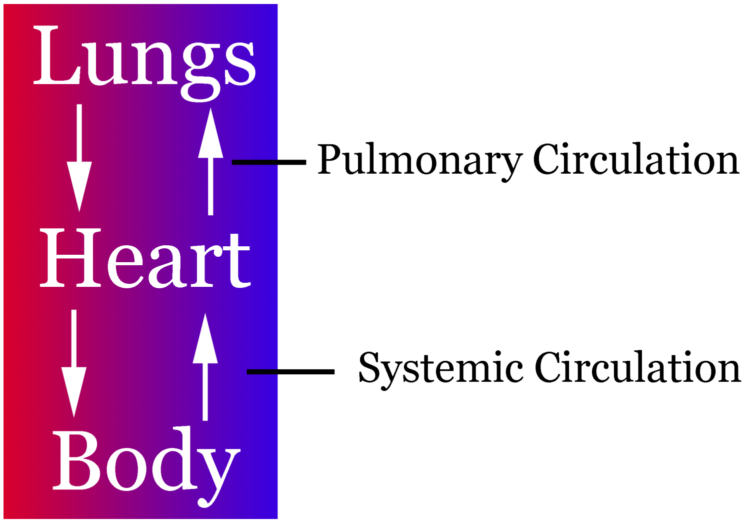


Figure 7.6: The double circulatory system. Trace the systemic circulation. Where is the path of pulmonary circulation?

The Lymphatic System

The **lymphatic system** is a network of vessels and tissues that carry a clear fluid called lymph. The lymphatic system, shown in **Figure** 7.7 spreads all around the body. **Lymph vessels** are tube-shaped, just like blood vessels. The lymphatic system works with the cardiovascular system to return body fluids to the blood. The lymphatic system and the cardiovascular system are often called the body's two "circulatory systems."

Role of the Lymphatic System in Circulation

You may think that your blood vessels have thick walls without any leaks, but it's not true! Blood vessels can leak just like any other pipe. The lymphatic system makes sure leaked blood returns back to the bloodstream.

When a small amount of fluid leaks out from the blood vessels, it collects in the spaces between cells and tissues. Some of the fluid returns to the cardiovascular system, and the rest is collected by the lymph vessels of the lymphatic system, which are shown in **Figure** 7.8. The fluid that collects in the lymph vessels is called **lymph**. The lymphatic system then returns the lymph to the cardiovascular system. Unlike the cardiovascular system, the lymphatic system is not closed and has no central pump (or heart). Lymph moves slowly in lymph vessels. It is moved along in the lymph vessels by the squeezing action of smooth muscles and skeletal muscles.

Role of the Lymphatic System in the Body's Defenses

The lymphatic system also plays an important role in the immune system. The lymphatic system makes white blood cells that protect the body from diseases.

Organs of the Lymphatic System

Along with the lymph vessels, lymph ducts, and lymph nodes, the lymphatic system also includes many organs. The tonsils, thymus, and spleen, which are shown in **Figure** 7.7, also help prevent diseases. Many of these organs are also part of the immune system.

Tonsils

If you open your mouth and look at your throat in a mirror, you may see some lumps in the back of your throat. These are your tonsils. **Tonsils** are areas of lymphatic tissue on either side of the throat **Figure** 7.9. There are also tonsils in the nasal cavity and behind the tongue. Like other organs of the lymphatic system, the tonsils are also part of the immune system. The immune system helps protect the body against infection. The tonsils are believed to help fight off nose and throat, and other upper respiratory tract infections such as colds. Tonsillitis is an infection of the tonsils that can cause a sore throat and fever.

Bone Marrow

Bone marrow is the tissue found in the middle of bones. The marrow in the large bones of adults makes new blood cells, like white blood cells, called T-cells. Other white blood cells, called B-cells, are also created in the bone marrow.

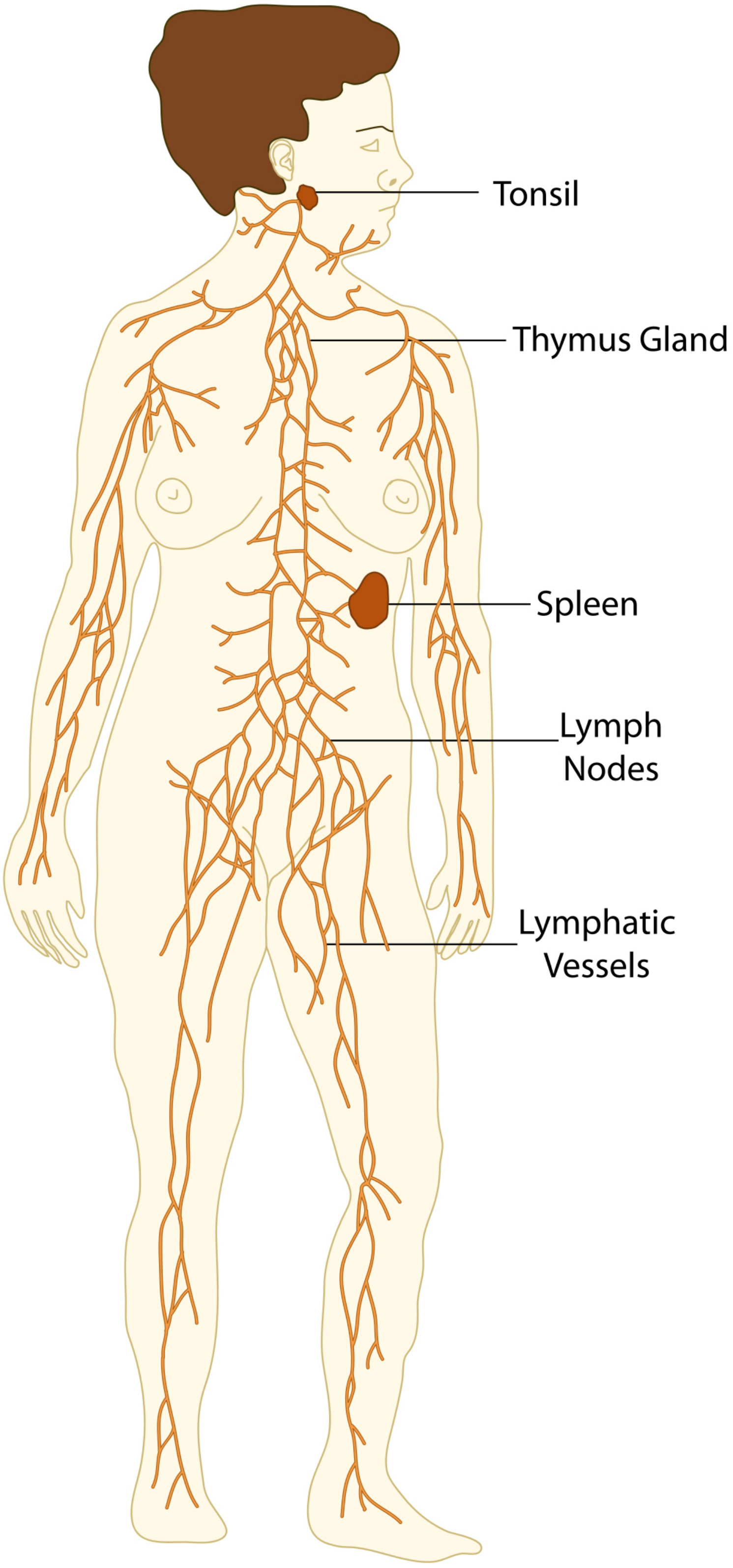


Figure 7.7: The lymphatic system helps return fluid that leaks from the blood vessels back to the cardiovascular system.

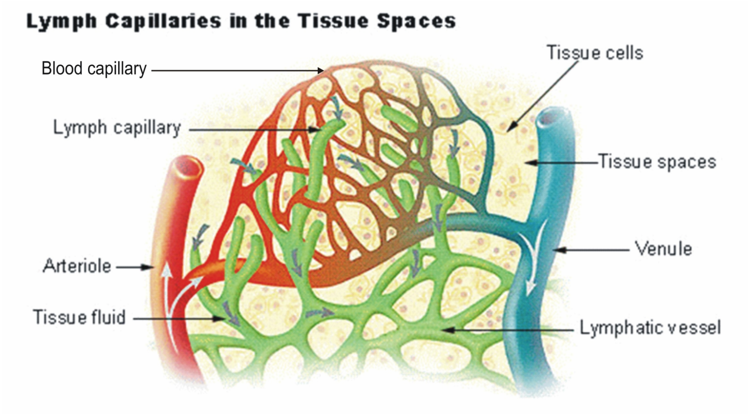


Figure 7.8: Lymph capillaries collect fluid that leaks out from blood capillaries.

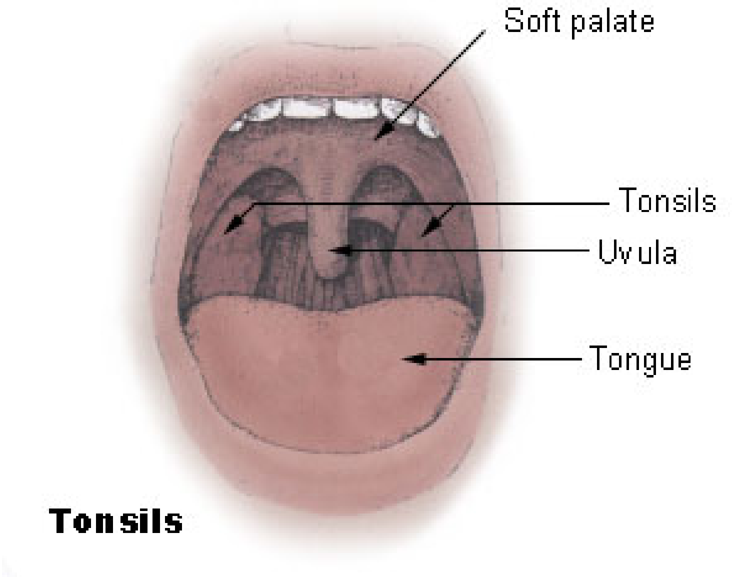


Figure 7.9: This image shows the tonsils in the back of the throat, but there are also tonsils in the nasal cavity and behind the tongue.

Thymus

The **thymus** is found in the upper chest. Chemicals made by the thymus help produce cells that fight infection. White blood cells called **lymphocytes** move from the bone marrow to the thymus to finish growing. The thymus grows to its largest size near puberty, and gets smaller as a person ages. If a person's thymus is surgically removed or damaged by disease while they are young, the person will be more prone to infection.

Spleen

The spleen is in the abdomen, as shown in **Figure** 7.10. In an area of the spleen called **red pulp**, materials are filtered from the blood, including old and dead red blood cells. The spleen also makes red blood cells. Areas called **white pulp** help fight infections by making white blood cells. If a person's spleen is surgically removed, or does not work properly, the person is at risk for certain infections. You can learn more about the roles of the lymphatic system and white blood cells in the *Diseases and the Body's Defenses* chapter.

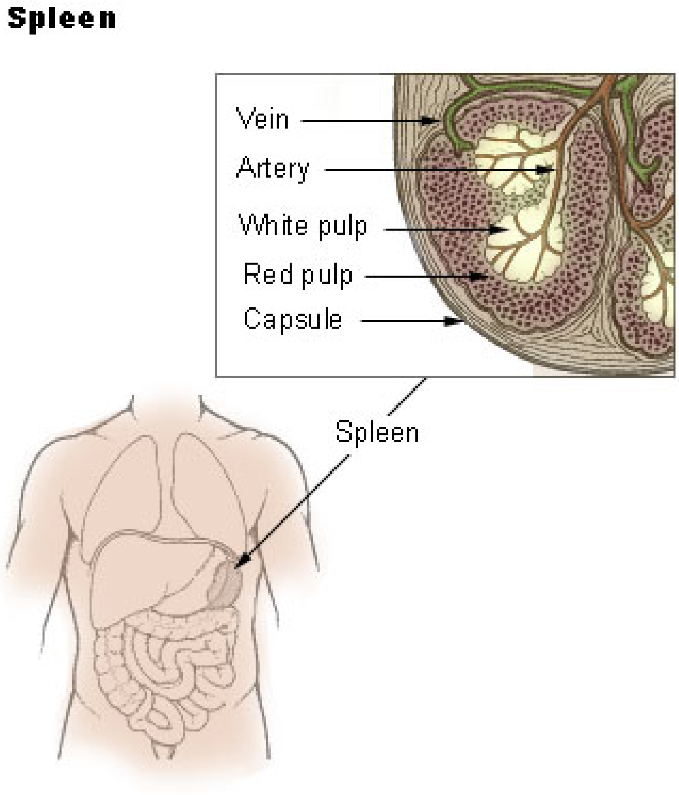


Figure 7.10: In the spleen, the white pulp makes white blood cells, while the red pulp acts like a filter and removes dead and dying cells from the blood.

Lesson Summary

- **Table** 7.1 summarizes the structures and functions of the cardiovascular and lymphatic systems.

Table 7.1: **Structures and Functions of the Cardiovascular and Lymphatic Systems**

System	Structure (organs and tissues)	Function
Lymphatic	Lymph vessels	Transport fluid (lymph) from between body cells back to blood
	Lymph nodes	Trap invading diseases and cells with cancer
	Spleen, tonsils, and adenoids	Trap invading diseases
	Thymus	where white blood cell (lymphocytes) grow larger
Cardiovascular	Blood vessels	Transport blood around the body
	Blood	Moves oxygen and nutrients; also carries white blood cells to sites of infection and inflammation
	Heart	Pumps blood around the body

- The cardiovascular system includes the heart, the blood vessels, and the blood.
- There are three main types of blood vessels in the body: arteries, veins, and capillaries.
- Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart.
- Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.
- Organs of the lymphatic system include the tonsils, thymus, and spleen.
- The lymphatic system works with the cardiovascular system to return body fluids to the blood.

Review Questions

Recall

1. Identify the three main parts of the cardiovascular system.
2. Identify three types of blood vessels found in the body.
3. Which blood vessels move blood away from the heart?
4. What are the smallest blood vessels in the body called?
5. Which blood vessels bring blood back to the heart?
6. Identify three main organs of the lymphatic system.
7. Name one function of tonsils.

Apply Concepts

8. Where does blood in the pulmonary system go after it leaves the heart?
9. Where does blood in systemic circulation go after it leaves the heart?
10. What does blood that leaves the heart in systemic circulation have that body cells need?
11. How do the cardiovascular and lymphatic systems work together?

12. What is lymph, and where does it come from?
13. What might happen if a person did not have a spleen?

Critical Thinking

14. Explain how there are actually two circulatory systems in the body.

Further Reading / Supplemental Links

- `http://en.wikipedia.org/wiki/Heart`

Points to Consider

Next we look further at the heart and blood vessels.

- How can the heart pump blood to the entire body?
- How do you think a hole in the heart muscle affect blood flow?

7.2 Heart and Blood Vessels

Lesson Objectives

- Describe the structure of the heart.
- Outline how blood moves through the heart.
- Describe the importance of valves in the heart.
- Describe the coronary circulation.

Check Your Understanding

- What is the role of the cardiovascular system?
- What is the main function of the heart?

Vocabulary

atrioventricular (AV) valves atrium semilunar (SL) valves
valves ventricle

The Heart

What is the heart? How does it pump blood? The heart is divided into four chambers, or spaces: the left and right atria, and the left and right ventricles. An **atrium** (singular for atria) is one of the two small, thin-walled chambers on the top of the heart where the blood first enters. A **ventricle** is one of the two muscular V-shaped chambers that pump blood out of the heart. You can remember they are called ventricles because they are shaped like a ”V.” The four chambers of the heart are shown in **Figure** 7.11.

The atria receive the blood, and the ventricles pump the blood out of the heart. Each of the four chambers of the heart has a specific job.

- The right atrium receives oxygen-poor blood from the body.
- The right ventricle pumps oxygen-poor blood toward the lungs.
- The left atrium receives oxygen-rich blood from the lungs.
- The left ventricle pumps oxygen-rich blood out of the heart to the rest of the body.

Where is the Heart?

The heart is closer to the center of the body than you may think. It is usually found in the left to middle of the chest, with the largest part of the heart slightly to the left. It always feels like the heart is on the left side of the body because the left ventricle is bigger and stronger than the right ventricle. The heart is also surrounded by the lungs.

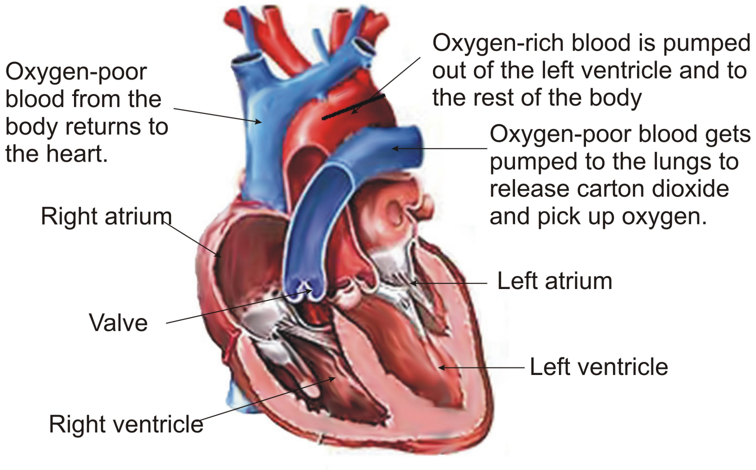

Oxygen-poor blood from the body returns to the heart.
Oxygen-rich blood is pumped out of the left ventricle and to the rest of the body
Oxygen-poor blood gets pumped to the lungs to release carton dioxide and pick up oxygen.
Right atrium
Left atrium
Valve
Left ventricle
Right ventricle

Figure 7.11: The atria receive blood and the ventricles pump blood out of the heart.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops. You can think of them as a “left side loop” and a “right side loop.” The right side of the heart collects oxygen-poor blood from the body and pumps it into the lungs, where it releases carbon dioxide and picks up oxygen. The left side carries the oxygen-rich blood back from the lungs into the left side of the heart, which then pumps the oxygen-rich blood to the rest of the body.

The Heartbeat

To move blood through the heart, the cardiac muscle needs to contract in an organized way. Blood first enters the atria, as shown in **Figure** 7.12. When the atria contract, blood is pushed into the ventricles. After the ventricles fill with blood, they contract, and blood is pushed out of the heart. So how is the blood kept from flowing back on itself?

Valves in the heart keep the blood flowing in one direction. You can see some of the valves in **Figure** 7.12. The valves do this by opening and closing in one direction only. Blood only moves forward through the heart. The valves stop the blood from flowing backward. There are four valves of the heart.

- The two atrioventricular (AV) valves stop blood from moving from the ventricles to the atria.
- The two semilunar (SL) valves are found in the arteries leaving the heart, and they prevent blood flowing back from the arteries into the ventricles.

Why does a heart beat? The “lub-dub” sound of the heartbeat is caused by the closing of the AV valves (”lub”) and SL valves (”dub”), after blood has passed through them.

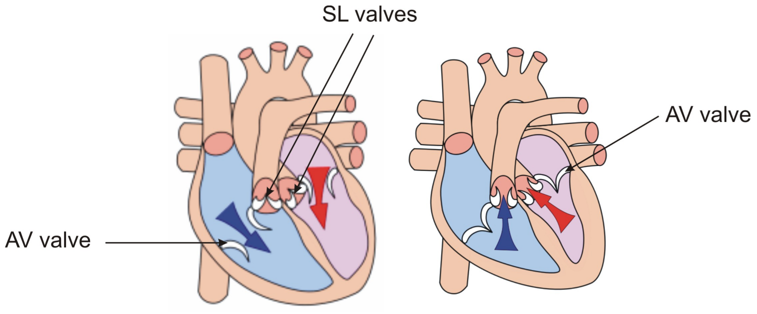


Figure 7.12: Blood flows in only one direction in the heart. Blood enters the atria, which contract and push blood into the ventricles. The atria relax and the ventricles fill with blood. Finally, the ventricles contract and push blood around the body.

Control of the Heartbeat

The heart is a made up of cardiac muscle cells. Cardiac cells are able to contract by themselves. They do not need help from the nervous system. This is different from skeletal muscle, which needs messages from nerves to contract. The number of times a heart contracts over a certain amount of time is called the **heart rate**. Exercising or getting scared can make the heart rate increase. After the exercise is over, or the fear has passed, the heart rate returns to normal.

Blood Circulation and Blood Vessels

The blood vessels are an important part of the cardiovascular system. They connect the heart to every cell in the body. Arteries carry blood away from the heart, while veins return blood to the heart. The main arteries and veins of the heart are shown in **Figure** 7.13.

Important Arteries and Veins

There are specific veins and arteries that are more significant than others. The pulmonary arteries carry oxygen-poor blood away from the heart to the lungs. These are the only arteries that carry oxygen-poor blood. The aorta is the largest artery in the body. It carries oxygen-rich blood away from the heart. Further away from the heart, the aorta branches into smaller arteries, which eventually branch into capillaries.

The veins that return oxygen-poor blood to the heart are the superior vena cava and the inferior vena cava. The **pulmonary veins** return oxygen-rich blood from the lungs to the heart. The pulmonary veins are the only veins that carry oxygen-rich blood.

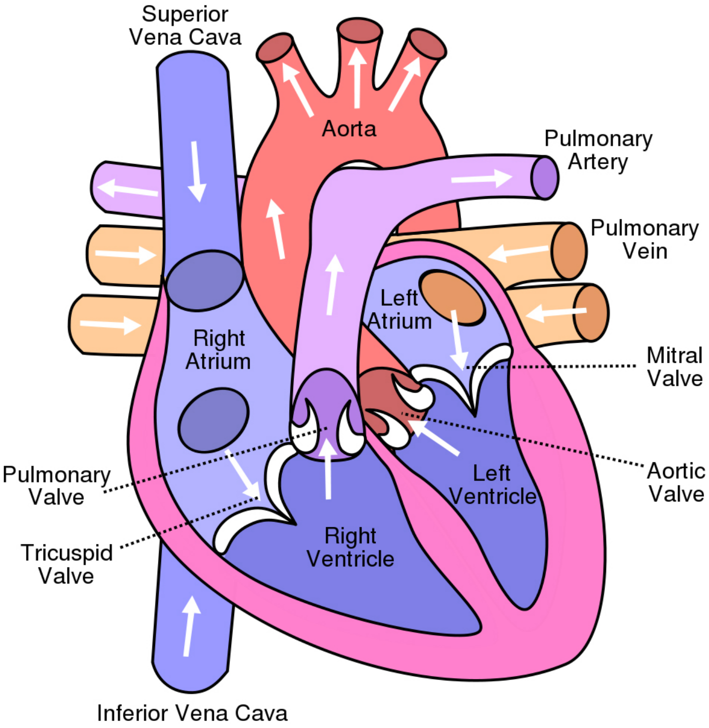


Figure 7.13: The right side of the heart pumps deoxygenated blood into pulmonary circulation, while the left side pumps oxygenated blood into systemic circulation.

Pulmonary Circulation

Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart and brings it to the lungs. Oxygen-poor blood returns to the heart from the body and leaves the right ventricle through the pulmonary arteries, which carry the blood to each lung. Once at the lungs, the red blood cells release carbon dioxide and pick up oxygen when you breathe. The oxygen-rich blood then leaves the lungs through the pulmonary veins, which return it to the left side of the heart. This completes the pulmonary cycle. The oxygenated blood is then pumped to the body through systemic circulation, before returning again to pulmonary circulation.

Systemic Circulation

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. Oxygen-rich blood leaves the left ventricle through the aorta, then it travels to the body's organs and tissues. The tissues and organs absorb the oxygen through the capillaries. Oxygen-poor blood is collected from the tissues and organs by tiny veins, which then flow into bigger veins, and eventually into the inferior vena cava and superior vena cava. This completes systemic circulation. The blood releases carbon dioxide and gets more oxygen in pulmonary circulation before returning to systemic circulation.

Lesson Summary

- The heart is divided into four chambers, the left and right atria and the left and right ventricles.

- The right side of the heart collects oxygen-poor blood from the body and pumps it into the lungs, where it releases carbon dioxide and picks up oxygen.
- The left-side carries the oxygen-poor blood back from the lungs into the left side of the heart, which then pumps the oxygen-poor blood to the rest of the body.
- The valves in the heart prevent blood from flowing backward into the heart.

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/William_Harvey
- http://thevirtualheart.org/anatomyindex.html
- http://en.wikipedia.org/wiki/Cardiac_cycle

Review Questions

Recall

1. Name the four chambers of the heart.
2. Where does oxygen-poor blood first enter the heart?
3. Do ventricles pump blood out of the heart, or do they pump blood into the atria?
4. Do the inferior vena cava and superior vena cava carry oxygen-poor or oxygen-rich blood?
5. To what organ or organs does systemic circulation bring blood?
6. To what organ or organs does pulmonary circulation bring blood?

Apply Concepts

7. Why can the heart be considered to be two separate pumps?
8. What is the purpose of the valves in the heart?

Critical Thinking

9. How might a hole in the heart wall between the two ventricles affect the circulation of blood?

Points to Consider

A more in-depth look at blood is next.

- How do different parts of the blood impact the cardiovascular system?
- How can diet affect how blood carries oxygen?

7.3 Blood

Lesson Objectives

- List the main parts of blood.

- Identify three functions of blood.
- Name the oxygen-carrying protein found in red blood cells.
- Identify the main function of white blood cells.
- Describe the importance of the ABO blood system.
- Identify three blood disorders or diseases.

Check Your Understanding

- What is the main function of the blood?
- What is the role of oxygen in aerobic (cellular) respiration?

Vocabulary

ABO blood type system antibody blood clotting
fibrin hemoglobin hemophilia
leukemia lymphoma platelets
red blood cells sickle cell disease universal donor
universal recipient white blood cells

Components of Blood

Did you know that blood is a tissue? Blood is a fluid connective tissue that is made up of red blood cells, white blood cells, platelets, and plasma. The cells that make up blood are shown in **Figure** 7.14. The different parts of blood have different roles.

Some of the roles of blood include:

- The defense of the body against diseases.
- The movement of chemical messages, such as hormones and hormone-like substances.
- The control of body temperature.
- The repair of damage to body tissues.

Plasma

If you were to filter out all the cells in blood, plasma is what would be left over. Plasma is the golden-yellow liquid part of the blood. Plasma is about 90 percent water and about 10 percent dissolved proteins, glucose, ions, hormones, and gases. Blood is made up mostly of plasma.

Red Blood Cells

Red blood cells (RBCs) are flattened, disk-shaped cells that carry oxygen. They are the most common blood cell in the blood. There are about 4 to 6 million RBCs per cubic millimeter of blood. Each RBC has 200 million molecules of hemoglobin. **Hemoglobin** is the protein that carries oxygen. Hemoglobin also gives the RBCs their red color.

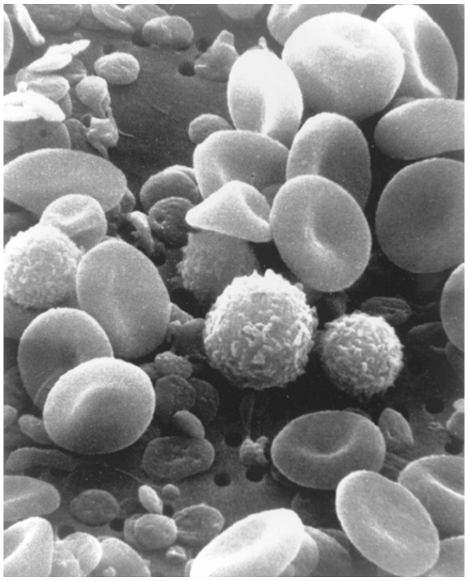


Figure 7.14: A scanning electron microscope (SEM) image of human blood cells. Red blood cells are the flat, bowl-shaped cells, the tiny disc-shaped pieces are platelets and white blood cells are the round cells shown in the center.

Red blood cells are made in the red marrow of long bones, ribs, skull, and vertebrae. Each red blood cell lives for only 120 days (about four months). After this time, they are destroyed in the liver and spleen. Red blood cells are shown in **Figure** 7.15. Mature RBCs do not have a nucleus or other organelles.

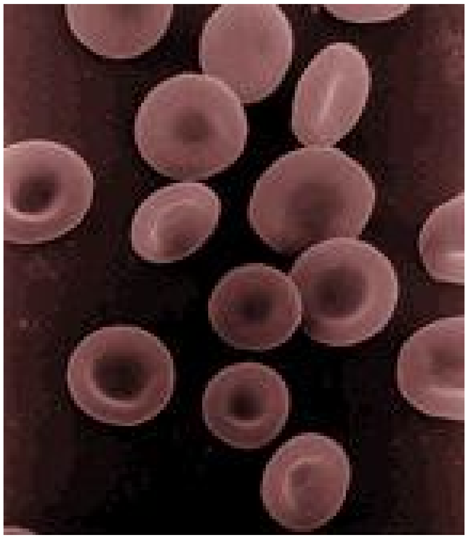


Figure 7.15: The flattened shape of RBCs helps them to carry more oxygen than if they were rounded.

White Blood Cells

White blood cells (WBCs) are usually larger than red blood cells. They have a nucleus but do not have hemoglobin. White blood cells make up less than one percent of the blood's volume. Most WBCs are made in the bone marrow, and some mature in the lymphatic system. WBCs defend the body against infection by bacteria, viruses, and other diseases. There are different WBCs with different jobs.

- Neutrophils can squeeze through capillary walls and swallow particles such as bacteria and parasites.
- Macrophages can also swallow and destroy old and dying cells, bacteria, or viruses. In **Figure** 7.16 a macrophage is attacking and swallowing two particles, possibly diseases. Macrophages also release chemical messages that cause the number of WBCs to increase.
- Lymphocytes fight infections caused by viruses and bacteria. Some lymphocytes attack and kill cancer cells. Lymphocytes called B-cells make antibodies. An **antibody** is a protein that finds harmful antigens and destroys them. To learn more about the role of WBCs in protecting the body from infection, see the *Diseases and the Body's Defenses* chapter.

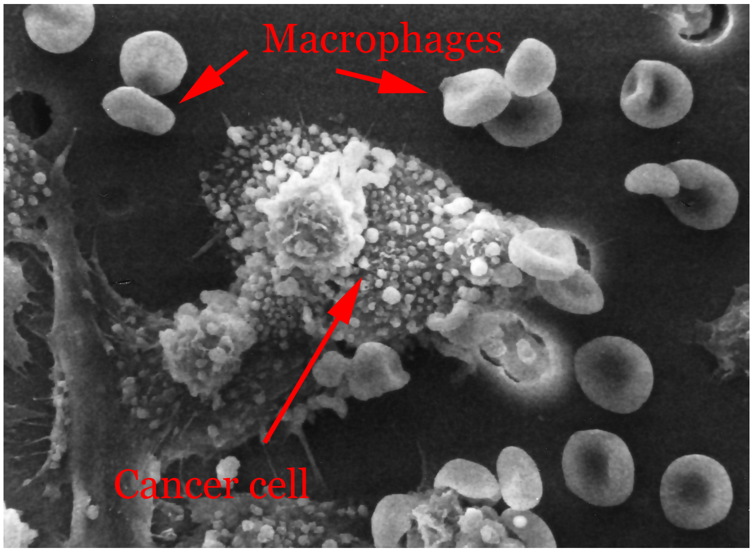


Figure 7.16: A type of WBC, called a macrophage, is attacking a cancer cell

Platelets

Platelets are very small, but they are very important in blood clotting. Platelets are not cells. They are sticky little pieces of larger cells. Platelets bud off large cells that stay in the bone marrow. A platelet sits between a RBC and a WBC in **Figure** 7.17. When a blood vessel gets cut, platelets stick to the injured areas. They release chemicals called clotting factors, which cause proteins to form over the wound. This web of proteins catches RBCs and forms a clot. This clot stops more blood from leaving the body through the cut blood vessel. The clot also stops bacteria from entering the body. Platelets survive in the blood for 10 days before they are removed by the liver and spleen.

Transport of Chemical Messages

The blood also acts as a messenge delivery service, like a post office. Chemical messengers called hormones are carried and brought to cells by the blood.

Control of Body Temperature

How do your blood vessels control your body temperature? Your blood also moves heat around your body. When your brain senses that your body temperature is increasing, it sends messages to the blood vessels

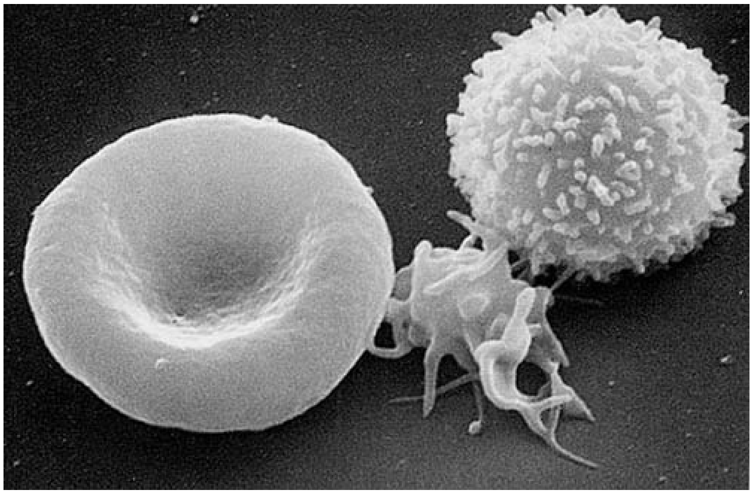


Figure 7.17: A platelet lies between a RBC, at left, and a WBC at right. Platelets are little pieces of larger cells that are found in the bone marrow.

in the skin to increase in diameter. Increasing the diameter of the blood vessels increases the amount of blood and heat that moves near the skin surface. The heat is then released from the skin. What do you think your blood vessels do when your body temperature is decreasing?

Blood Clotting

Blood clotting is a complex process by which blood forms solid clots. As discussed above, clotting is important to stop bleeding and begin the repair of damaged blood vessels. Blood clotting disorders can lead to an increased risk of bleeding or clotting inside a blood vessel. Platelets are important for the proper clotting of blood.

Clotting is started almost immediately when an injury damages the inside lining of a blood vessel. The steps involved in clotting are described below:

1. Platelets clump together, forming a clot at the injury site.
2. Proteins in the plasma cause a chemical reaction that brings a protein called **fibrin** to the site.
3. The fibrin forms a web across the platelet clot, trapping red blood cells.
4. This mass of platelets, fibrin, and red blood cells forms a clot that turns into a scab.

Certain nutrients are needed for the clotting system to work properly. Two of these are calcium and vitamin K. Bacteria that live in your intestines make enough vitamin K, so you do not need to eat extra vitamin K in your food.

Blood Types

Do you know what your blood type is? Maybe you have heard someone say that they some Type A or Type O blood. Blood type is a way to describe the type of antigens, or proteins, on the surface of red blood cells (RBCs). There are four blood types; A, B, AB, and O.

1. Type A blood has type A antigens on the RBCs in the blood.
2. Type AB blood has A and B antigens on the RBCs.

3. Type B has B antigens on the RBCs.
4. Type O does not have any antigens.

The ABO blood group system is important if a person needs a blood transfusion. A blood transfusion is the process of putting blood or blood products from one person into the circulatory system of another person. Blood also has different types of antibodies, or proteins released by the blood cells that attack other strange substances or diseases in the body. Different blood types have different antibodies (see chart below). What type of antibodies do people with Type O blood produce? Anti-A and anti-B antibodies. This means that if a person with type O blood received type A blood, the anti-A antibodies in the person's blood would attack the A antigens on the RBCs in the donor blood, as shown in **Figure** 7.18. The antibodies would cause the RBCs to clump together, and the clumps could block a blood vessel. This clumping of blood cells could cause death.

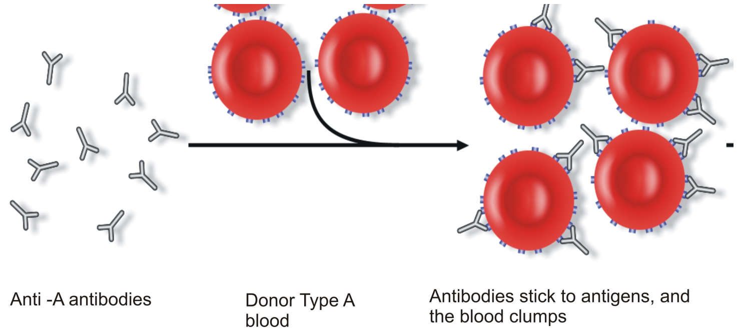


Figure 7.18: A person with type O blood has A and B antibodies in their plasma; if the person was to get type A blood instead of type O, Their A antibodies would attach to the antigens on the RBCs and cause them to clump together.

The Rhesus System

The second most important blood group system in human blood is the Rhesus (Rh) system. A person either has, or does not have, the Rh antigen on the surface of their RBCs. If they do have it, then the person is positive. If the person does not have the antigen, they are considered negative.

Blood Donors

Recall that people with type O blood do not have any antigens on their RBCs. As a result, type O blood can be given to people with blood types A, B, or AB. If there are no antigens on the RBCs, there cannot be an antibody reaction in the blood. People with type O blood are often called **universal donors.**

The blood plasma of AB blood does not contain any anti-A or anti-B antibodies. People with type AB blood can receive any ABO blood type. People with type AB positive blood are called **universal recipients** because they can receive any blood type. The antigens and antibodies that define blood type are listed in **Table** 7.2.

Table 7.2: **Blood Types, Antigens, and Antibodies**

Blood type	Antigen type	Plasma antibodies	Can receive blood from types	Can donate blood to types
A	A	anti-B	A,O	A, AB
B	B	anti-A	B,O	B, AB
AB	A and B	none	AB, A, B, O	AB
O	none	anti-A, anti-B	O	AB, A, B, O

Blood Diseases

Problems can occur with red blood cells, white blood cells, platelets, and other parts of the blood. Many blood disorders are genetic, meaning they are inherited from a parent. Some blood diseases are caused by not getting enough of a certain nutrient, while others are cancers of the blood.

Sickle-Cell Disease

Sickle-cell disease is a blood disease that is caused by abnormally-shaped blood protein hemoglobin. Many of the RBCs of a person with sickle cell disease are long and curved (sickle-shaped), as shown in **Figure** 7.19. The long, sickle-shaped RBCs can have damaged cell membranes, which can cause them to burst. The long shape of the cells can cause them to get stuck in narrow blood vessels. This clotting means that oxygen cannot reach the cells. People with sickle-cell disease are most often well, but can occasionally have painful attacks. The disease is not curable, but can be treated with medicines.

There is an advantage, however, to sickle-cell disease. People who are carriers for the sickle cell gene, or who are heterozygous, are resistant to severe malaria. See the *Genetics* chapter for further information.

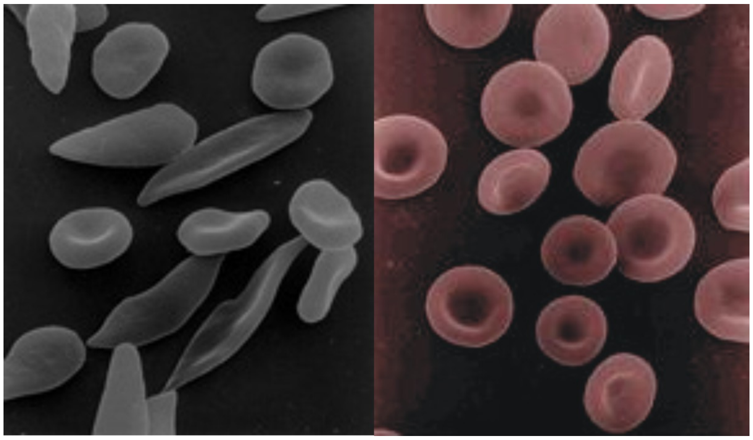


Figure 7.19: The RBCs of a person with sickle-cell disease (left) are long and pointed, rather than straight, like normal cells (right). The abnormal cells cannot carry oxygen properly and can get stuck in capillaries.

Anemia

Anemia is a disease that occurs when there is not enough hemoglobin in the blood to carry oxygen to body cells. Hemoglobin normally carries oxygen from the lungs to the tissues. Anemia leads to a lack of oxygen in organs.

Anemia is usually caused by one of the following:

- A loss of blood from a bleeding wound or a slow leak of blood.
- The destruction of RBCs.
- A lack of RBC production.

Anemia may not have any symptoms. Some people with anemia feel weak or tired in general or during exercise. They also may have poor concentration. People with more severe anemia often get short of breath during activity. Iron-deficiency anemia is the most common type of anemia. It occurs when the body does not receive enough iron. Since there is not enough iron, hemoglobin, which contains iron, cannot be made.

In the United States, 20 percent of all women of childbearing age have iron deficiency anemia, compared with only 2 percent of adult men. The most common cause of iron deficiency anemia in young women is blood lost during menstruation. Iron deficiency anemia can be avoided by getting the recommended amount of iron in one's diet. Anemia is often treated or prevented by taking iron supplements.

Boys and girls between the ages of 9 and 13 should get 9 mg of iron every day. Girls between the ages of 14 and 18 should get 15 mg of iron every day. Boys between the ages of 14 and 18 should get 11 mg of iron every day. Pregnant women need the most iron — 27 mg daily.

Good sources of iron include shellfish, such as clams and oysters. Red meats, such as beef, are also a good source of iron. Non-animal sources of iron include seeds, nuts, and legumes. Breakfast cereals often have iron added to them in a process called fortification. Some good sources of iron are listed in **Table** 7.3. Eating vitamin C along with iron-containing food increases the amount of iron that the body can absorb.

Table 7.3: **Sources of Iron**

Food	Milligrams (mg) of Iron
Canned clams, drained, 3 oz	23.8
Fortified dry cereals, about 1 oz	1.8 to 21.1
Roasted pumpkin and squash seeds, 1 oz	4.2
Cooked lentils, ½ cup	3.3
Cooked fresh spinach, ½ cup	3.2
Cooked ground beef, 3 oz	2.2
Cooked sirloin beef, 3 oz	2.0

Leukemia

Leukemia is a cancer of the blood or bone marrow. It is characterized by an abnormal production of blood cells, usually white blood cells. **Lymphoma** is a type of cancer in white blood cells called *lymphocytes.* There are many types of lymphoma.

Hemophilia

Hemophilia is the name of a group of sex-linked hereditary diseases that affect the body's ability to control blood clotting. Hemophilia is caused by a lack of clotting factors in the blood. Since people with hemophilia cannot produce clots, any cut can put a person at risk of bleeding to death. The risk of internal bleeding is also increased in hemophilia, especially into muscles and joints.

Lesson Summary

- Blood is a fluid connective tissue that contains red blood cells, white blood cells, platelets, and plasma.
- The red blood cells give blood its red color.
- Blood carries oxygen and nutrients to body cells and carries wastes away. It also helps to maintain body temperature and to carry chemical messengers called hormones around the body.
- Hemoglobin is the oxygen-carrying protein that is found in red blood cells.
- White blood cells defend the body against infection by bacteria, viruses and other pathogens.
- Blood type is determined by the presence or absence of certain molecules, called antigens, on the surface of red blood cells (RBCs).
- There are four blood types; A, B, AB, and O.
- If a person receives the wrong blood type, antibodies in the recipient's blood will attack the antigens on the RBCs in the donor blood.
- Sickle-cell disease is a blood disease that is caused by abnormally-shaped hemoglobin, and important blood protein.
- Anemia is a disorder caused by a lack of hemoglobin in the blood.

Review Questions

Recall

1. What types of cells are found in blood?
2. What is the liquid part of blood called?
3. What is the function of platelets?
4. Identify one other function of blood other than bringing oxygen to body cells.
5. What is the oxygen-carrying protein found in red blood cells?
6. Identify two ways that white blood cells defend the body from infection.
7. Identify three blood disorders or diseases.
8. Identify two good sources of iron in the diet.

Apply Concepts

9. How are the red blood cells of the different blood groups different?
10. Why are people with type O blood called "universal donors?"
11. Why are people with type AB blood called "universal recipients?"
12. What is a common cause of anemia in young people?

Critical Thinking

13. How can the shape of the hemoglobin protein in a person with sickle-cell disease affect other body systems?

Further Reading / Supplemental Links

- http://www.nhlbi.nih.gov/health/dci/Diseases/Sca/SCA_WhatIs.html
- http://www.leukemia-lymphoma.org/all_page?item_id=7026
- http://en.wikipedia.org/wiki

Points to Consider

The health of the cardiovascular system is next.

- Why do you think the blood in veins not under pressure?
- How might your diet affect your cardiovascular system?

7.4 Health of the Cardiovascular System

Lesson Objectives

- Outline the cause of blood pressure in arteries.
- Identify the healthy range for blood pressure.
- Describe three types of cardiovascular disease.
- Identify things you can do to avoid cardiovascular disease.

Check Your Understanding

- What is the role of the cardiovascular system?

Vocabulary

angina atherosclerosis blood pressure
cardiovascular disease (CVD) coronary heart disease heart attack
hypertension plaque stroke

Blood Vessels and Blood Pressure

The health of your whole body depends on the good health of your cardiovascular system. **Blood pressure** occurs when circulating blood puts pressure on the walls of blood vessels. The pressure causes the walls of the arteries to move in a rhythmic fashion.

Blood in arteries is under the greatest amount of pressure. A person's pulse is the throbbing of their arteries that results from the heart beat. The pressure of the circulating blood slowly decreases as blood moves from the arteries, and into the smaller blood vessels. Blood in veins is not under pressure.

The **systolic** pressure is the highest pressure in the arteries. The **diastolic** pressure is the lowest pressure. Pressure in arteries is most commonly measured by an instrument called a **sphygmomanometer**, shown in **Figure** 7.20. The height of the column of mercury shows the pressure of the circulating blood. Many modern blood pressure devices no longer use mercury, but values are still reported in millimeters of mercury (mm Hg).

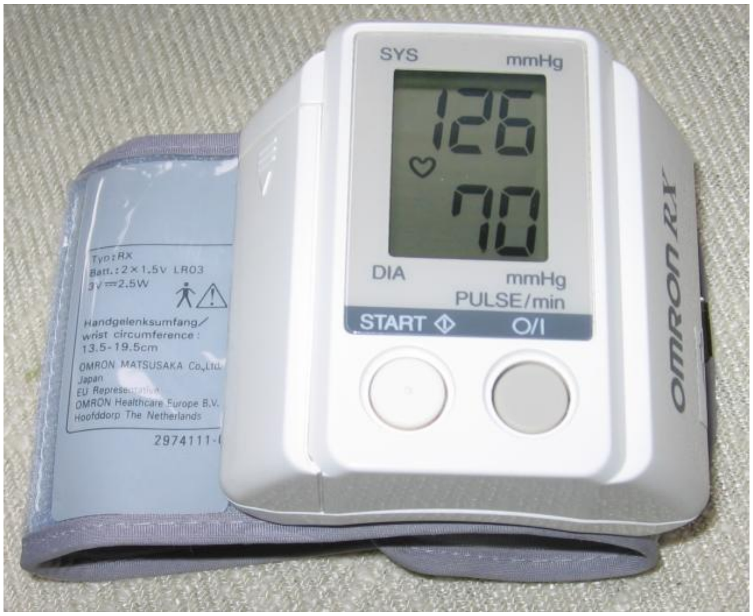


Figure 7.20: A digital sphygmomanometer is made of an inflatable cuff and a pressure meter to measure blood pressure.

Healthy Blood Pressure Ranges

Healthy ranges for blood pressure are:

- Systolic: less than 120 mm Hg
- Diastolic: less than 80 mm Hg

Blood pressure is usually written as systolic/diastolic mm Hg. For example, a reading of 120/80 mm Hg is said as ”one twenty over eighty.” These measures of blood pressure can change with each heartbeat and over the course of the day. Age, gender and race also influence blood pressure values. Pressure also varies with exercise, emotions, sleep, stress, nutrition, drugs, or disease.

Studies have shown that people whose systolic pressure is around 115 mm Hg rather than 120 mm Hg have fewer health problems. Clinical trials have shown that people who have blood pressures at the low end of these ranges have much better long term cardiovascular health.

Hypertension, which is also called ”high blood pressure,” occurs when a person’s blood pressure is always high. Hypertension is said to be present when a person’s systolic blood pressure is always 140 mm Hg or higher, and/or their diastolic blood pressure is always 90 mm Hg or higher. Having hypertension increases a person’s chance for developing heart disease, having a stroke, and other serious cardiovascular diseases. Hypertension often does not have any symptoms, so a person may not know they have high blood pressure. For this reason, hypertension is often called the silent killer. Treatments for hypertension include diet changes, exercise, and medication.

Atherosclerosis and Other Cardiovascular Diseases

A **cardiovascular disease (CVD)** is any disease that affects the cardiovascular system. But the term is usually used to describe diseases that are linked to atherosclerosis.

Atherosclerosis is an inflammation of the walls of arteries that causes swelling and a buildup of material called plaque. **Plaque** is made of cell pieces, fatty substances, calcium, and connective tissue that builds up around the area of inflammation. As a plaque grows, it stiffens and narrows the artery, which decreases the flow of blood through the artery, shown in **Figure** 7.21.

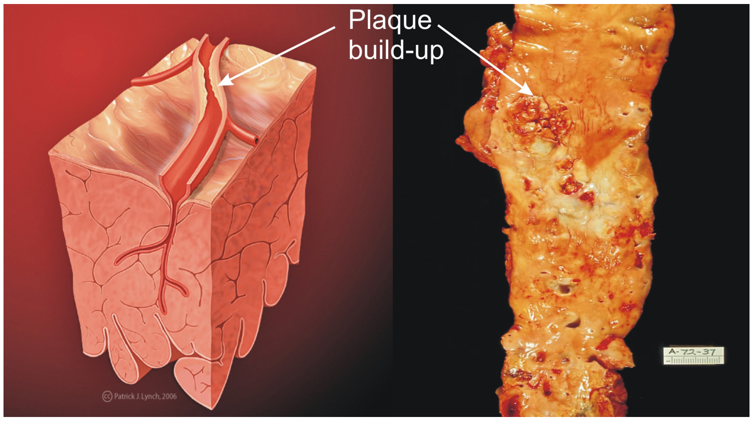


Figure 7.21: Atherosclerosis is sometimes referred to as hardening of the arteries; plaque build-up decreases the blood flow through the artery.

Atherosclerosis

Atherosclerosis normally begins in later childhood, and is usually found in most major arteries. It does not usually have any early symptoms. Causes of atherosclerosis include a high-fat diet, high cholesterol, smoking, obesity, and diabetes. Atherosclerosis becomes a threat to health when the plaque buildup prevents blood circulation in the heart or the brain. A blocked blood vessel in the heart can cause a heart attack. Blockage of the circulation in the brain can cause a stroke. According to the American Heart Association, atherosclerosis is a leading cause of CVD.

Coronary Heart Disease

Hearts have arteries that require oxygen, too. Muscle cells in the heart are given oxygen by **coronary arteries**. Blocked flow in a coronary artery can result in a lack of oxygen and the death of heart muscle. **Coronary heart disease** is the end result of the buildup of plaques within the walls of the coronary arteries.

Coronary heart disease often does not have any symptoms. A symptom of coronary heart disease is chest pain. Occasional chest pain, called **angina** can happen during times of stress or physical activity. The pain of angina means the heart muscle fibers need more oxygen than they are getting. Most people with coronary heart disease often have no symptoms for many years until they have a heart attack.

A **heart attack** happens when the blood cannot reach the heart because a blood vessel is blocked. If cardiac muscle is starved of oxygen for more than about five minutes, it will die. Cardiac muscle cells cannot be replaced, so once they die, they are dead forever. Coronary heart disease is the leading cause of death of adults in the United States. How a blocked coronary artery can cause a heart attack, and cause part of the heart muscle to die, is shown in **Figure** 7.22. If part of the cardiac muscle becomes injured, the heart will not work as well as it used to.

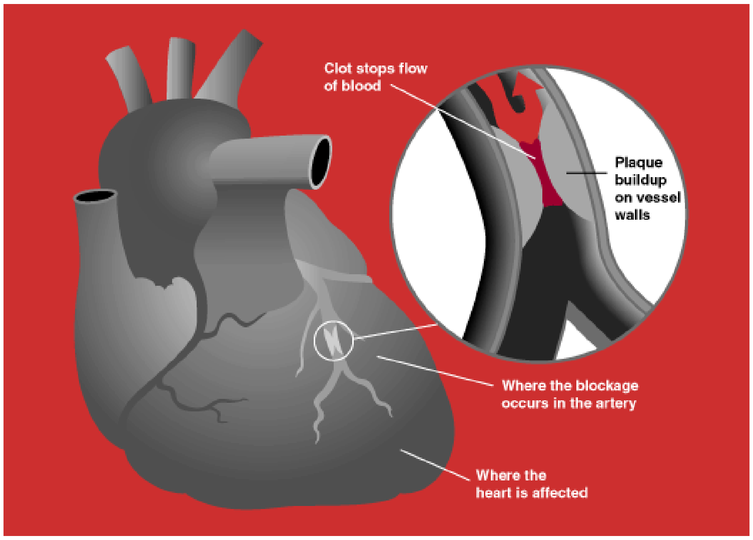

Clot stops flow of blood
Plaque buildup on vessel walls
Where the blockage occurs in the artery
Where the heart is affected

Figure 7.22: A blockage in a coronary artery stops oxygen getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

Stroke

Atherosclerosis in the arteries of the brain can also lead to a stroke. A **stroke** is a loss of brain function due to a blockage of the blood supply to the brain. It can be caused by a blood clot, an object that gets caught in a blood vessel, or by a bleeding blood vessel. Risk factors for stroke include old age, high blood pressure, having a previous stroke, diabetes, high cholesterol, and smoking. The best way to reduce the risk of stroke is to have low blood pressure. Many other risk factors, however, such as avoiding or quitting smoking are also important.

Keeping Your Cardiovascular System Healthy

There are many risk factors that can cause a person to develop CVD. A **risk factor** is anything that is linked to an increased chance of developing a disease or an infection. Some of the risk factors for CVD you cannot control, but there are many risk factors you can control.

Risk factors you cannot control include:

- **Age**: the older a person is, the greater their chance of developing a cardiovascular disease.
- **Gender**: men under age 64 are much more likely to die of coronary heart disease than women, although the gender difference decreases with age.
- **Genetics**: family history of cardiovascular disease increases a person's chance of developing heart disease.

Risk factors you can control include:

- **Tobacco smoking**: giving up smoking or never starting to smoke is the best way to reduce the risk of heart disease.

- **Diabetes**: diabetes can cause bodily changes, such as high cholesterol levels, which are are risk factors for CVD.
- **High cholesterol levels**: high amounts of low-density lipids in the blood, also called "bad cholesterol," increase the risk of CVD.
- **Obesity**: being obese, especially if the fat is mostly found in the upper body, rather than the hips and thighs, increases risk significantly.
- **High blood pressure**: hypertension can cause atherosclerosis.
- **Lack of physical activity**: aerobic activities, such as the one shown in **Figure** 7.23, help keep your heart healthy. To reduce the risk of disease, you should be active for at least 60 minutes a day, five days a week.
- **Poor eating habits**: eating mostly foods that do not have many nutrients other than fat or carbohydrate leads to high cholesterol levels, obesity and CVD (**Figure** 7.24).

Figure 7.23: Sixty minutes a day of vigorous aerobic activity, such as basketball, is enough to help keep your cardiovascular system healthy.

Figure 7.24: The USDA's MyPyramid recommends that you limit the amount of such foods in your diet to occasional treats.

Lesson Summary

- Blood pressure is the force put on the walls of blood vessels by circulating blood.
- The force put on the walls of arteries is called blood pressure.
- Blood pressure is measured by an instrument called a sphygmomanometer.
- In the United States, the healthy ranges for systolic pressure is less than 120 mm Hg and a diastolic pressure of less than 80 mm Hg.
- Hypertension occurs when a person's blood pressure is always high.
- A cardiovascular disease (CVD) is any disease that affects the cardiovascular system. Atherosclerosis, coronary heart disease, and stroke are examples of CVDs.
- Cardiovascular diseases are lifestyle diseases. Having a poor diet and not getting enough exercise are two major causes of CVD.

Review Questions

Recall

1. What is the cause of blood pressure?
2. What is the healthy range for blood pressure?
3. When is a person considered to have hypertension?
4. What is atherosclerosis?
5. What are three risks factor for cardiovascular disease?

Apply Concepts

6. How is the pulse related to blood pressure?
7. Is the blood in veins under pressure? Explain your answer.
8. Why is hypertension called a silent killer?

9. A stroke could be thought of as a "brain attack," in a similar way to a heart attack. How are strokes and heart attacks similar?

10. What is the difference between a controllable risk factor and an uncontrollable risk factor?

11. Why are cardiovascular diseases called lifestyle diseases?

Critical Thinking

12. One of your friends says, "Heart disease is genetic and people have it in my family, so there is nothing I can do about it." Explain to your friend how cardiovascular disease can be a lifestyle choice. Also, give your friend three recommendations on things he/she can do to prevent cardiovascular disease.

Further Reading / Supplemental Links

- http://bio-alive.com/animations/cardiovascular.htm
- http://mypyramid.gov http://www.presidentschallenge.org/; http://mypyramid.gov
- http://www.cdc.gov/youthcampaign/marketing/tweens/yellowball/index.htm
- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/recommendations/index.htm
- http://www.cdc.gov/bloodpressure http://en.wikipedia.org/wiki/Aerobic_exercise; http://www.cdc.gov/bloodpressure

Points to Consider

Next we take a look at the respiratory system.

- Do you think there is a relationship between the cardiovascular system and the respiratory system? What could it be?
- Do you think hypertension affects the ability of the blood to release carbon dioxide and pick up oxygen in the lungs? Why?

Image Sources

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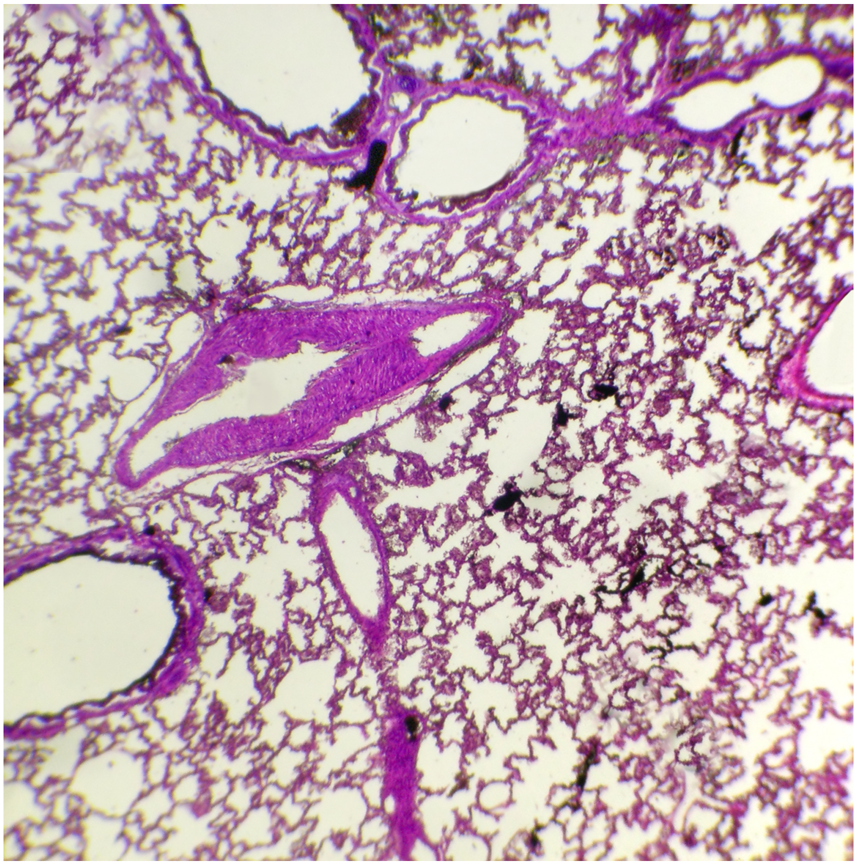
Chapter 8

MS Respiratory and Excretory Systems



The above image shows the tissue found inside of the lungs. The lungs contain alveoli. Alveoli absorb oxygen and send it to the blood vessels. They also move carbon dioxide from the blood vessels back to the lungs to be exhaled.

Alveoli look like clumps of grapes. Why do you think it is important that your body have many alveoli? What would happen if your alveoli lost their ability to function? Why do you think alveoli are shaped like spheres?

The respiratory system is important because it brings oxygen to cells in your body. But it also removes a waste, carbon dioxide. Another system in your body, the excretory system, also removes wastes. The excretory system moves waste from your digestive system and from your blood out of your body.

How do the respiratory system and excretory system work together? How does damage in one system affect the other? Consider these questions about respiration and waste removal as you read the following chapter.

8.1 The Respiratory System

Lesson Objectives

- Identify the parts of the respiratory system.
- Identify the main function of the respiratory system.
- Describe how breathing works.
- Outline how the respiratory system and the cardiovascular system work together.
- Identify how breathing and cellular respiration are connected.

Check Your Understanding

- What is an organ system?
- What is the role of the circulatory system?
- How does your blood get oxygen?

Vocabulary

alveoli diaphragm epiglottis
exhalation external respiration gas exchange
inhalation internal respiration larynx
pharynx respiration respiratory system
trachea

Roles of the Respiratory System

You breathe mostly without thinking about it. Remember how uncomfortable you felt the last time you had a cold or a cough? You usually do not think about your respiratory system or how it works until there is a problem with it. Every cell in your body depends on your respiratory system.

Your **respiratory system** is made up of the tissues and organs that allow oxygen to enter the body and carbon dioxide to leave your body. Organs in your respiratory system include your:

- Nose.
- Mouth.
- Larynx.
- Pharynx.
- Lungs.
- Diaphragm.

These structures are shown in **Figure** 8.1.

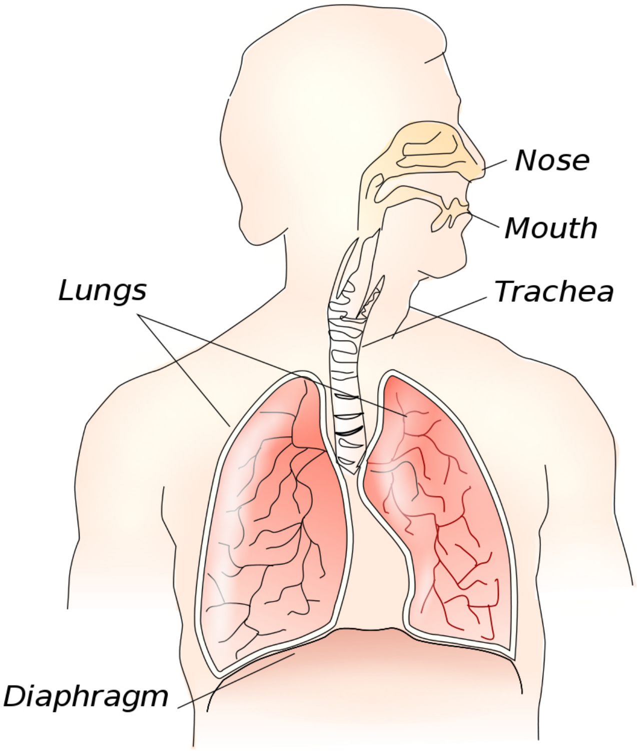


Figure 8.1: The respiratory system. Air moves in through the nose and mouth and down the trachea, which is a long, straight tube in the chest.

Parts of the Respiratory System

Figure 8.1 shows many of the structures of the respiratory system. Each of the parts has a specific job. The parts of the respiratory system include the following:

- The **diaphragm** is a sheet of muscle that spreads across the bottom of the rib cage. When the diaphragm contracts, the chest volume gets larger and the lungs take in air. When the diaphragm relaxes, the chest volume gets smaller and air is pushed out of the lungs.
- The nose and nasal cavity filter, warm, and moisten the air you breathe. The nose hairs and mucus produced by the cells in the nose catch particles in the air and keep them from entering the lungs. When particles in the air do reach the lungs, what do you think happens?
- Behind the nasal cavity, air passes through the **pharynx**, a long tube. Both food and air pass through the pharynx.
- The **larynx**, also called the ”voice box,” is found just below the pharynx. Your voice comes from your larynx. Air from the lungs passes across thin tissues in the larynx and produces sound.
- The **trachea**, or windpipe, is a long tube that leads down to the lungs, where it divides into the right and left **bronchi**. The bronchi branch out into smaller bronchioles in each lung.
- Since food goes down the pharynx, how is it stopped from entering the trachea? A flap of tissue called the *epiglottis* closes over the trachea when food is swallowed to prevent choking or inhaling food.

- The bronchioles lead to the alveoli. **Alveoli** are the little sacs at the end of the bronchioles. They look like little bunches of grapes, as shown in **Figure** 8.2. Oxygen is exchanged for carbon dioxide in the alveoli. **Gas exchange** is the name we give to the process that allows oxygen to enter the blood and carbon dioxide to move out of the blood - the two gases are ”exchanged.”

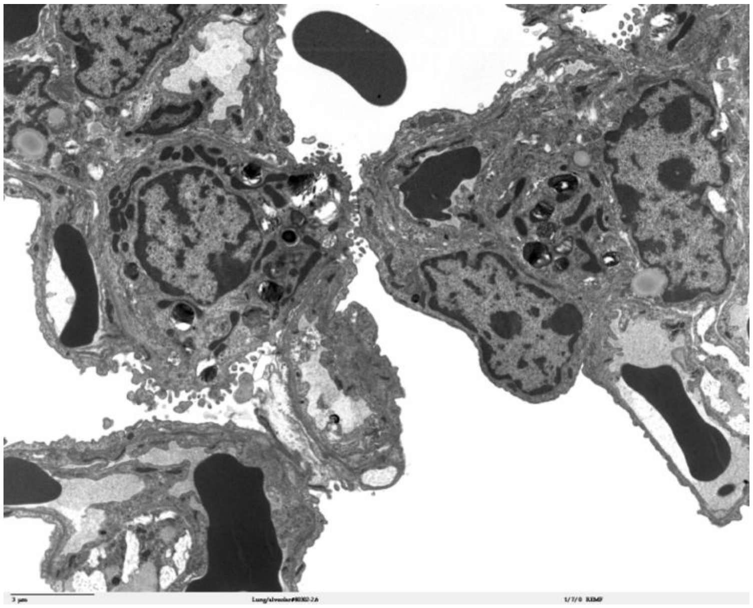


Figure 8.2: The alveoli are the tiny grape-like structures in the lungs and the sites of gas exchange.

How We Breathe

Most of the time, you breathe without thinking about it. Breathing is mostly an involuntary action that is controlled by a part of your brain that also controls your heart beat. If you swim, do yoga, or sing, you know you can also control your breathing. Taking air into the body through the nose and mouth is called **inhalation**. Pushing air out of the body through the nose or mouth is called **exhalation**. The man in **Figure** 8.3 is exhaling before he surfaces from the pool water.

How do lungs allow air in? As mentioned above, air moves into and out of the lungs by the movement of muscles. The diaphragm and rib muscles contract and relax to move air into and out of the lungs. During inhalation, the diaphragm contracts and moves downward. The rib muscles contract and cause the ribs to move outward. This causes the chest volume to increase. Because the chest volume is larger, the air pressure inside the lungs is lower than the air pressure outside. This difference in air pressures causes air to be sucked into the lungs. When the diaphragm and rib muscles relax, air is pushed out of the lungs. Exhalation is similar to letting the air out of a balloon.

The walls of the alveoli are very thin and allow gases to enter into them. The alveoli are lined with capillaries. These capillaries are shown in **Figure** 8.4. Oxygen moves from the alveoli to the blood in the capillaries that surround the alveoli. At the same time, carbon dioxide moves in the opposite direction, from capillary blood to the alveoli.

Breathing and Respiration

When you breath in, oxygen is drawn in through the mouth and down into the lungs. The oxygen then passes across the thin lining of the capillaries and into the blood. The oxygen molecules are carried to the

Figure 8.3: Being able to control breathing is important for many activities, such as swimming. The man in the photograph is exhaling before he surfaces from the water.

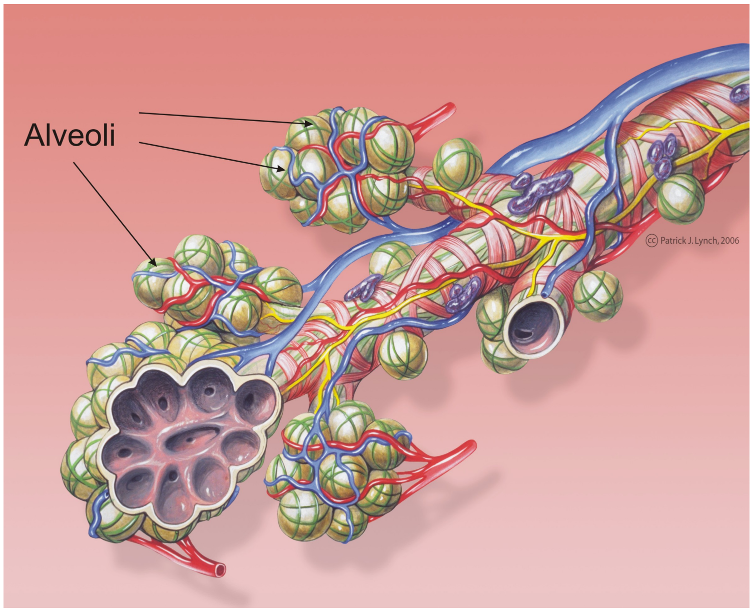


Figure 8.4: The bronchi and alveoli. During respiration, oxygen gets pulled into the lungs and enters the blood by passing across the thin alveoli membranes and into the capillaries.

body cells by the blood. Carbon dioxide from the body cells is carried by the blood to the lungs where it is released into the air. The process of getting oxygen into the body and releasing carbon dioxide is called **respiration**.

Sometimes breathing is called respiration, but there is much more to respiration than just breathing. There are actually two parts to respiration, external respiration and internal respiration. **External respiration** is the movement of oxygen into the body and carbon dioxide out of the body. **Internal respiration** is the exchange of oxygen and carbon dioxide between the blood and the cells of the body (**Figure** 8.5).

The Journey of a Breath of Air

Breathing is only part of the process of bringing oxygen to where it is needed in the body. After oxygen enters the lungs, what happens?

1. The oxygen enters the blood stream from the alveoli. Then, the oxygen-rich blood returns to the heart.
2. Oxygen-rich blood is then pumped through the aorta.
3. From the aorta, oxygen-rich blood travels to the smaller arteries and finally to the capillaries.
4. The oxygen molecules move out of the capillaries and into the body cells.
5. While oxygen moves from the capillaries and into body cells, carbon dioxide moves from the cells into the capillaries.

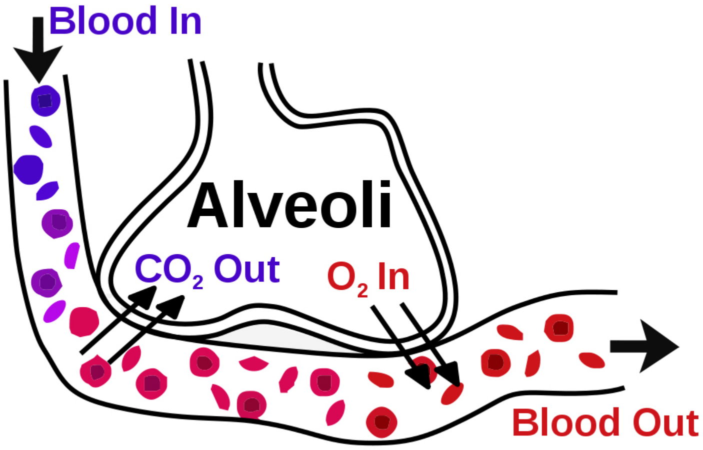


Figure 8.5: Gas exchange is the movement of oxygen into the blood and carbon dioxide out of the blood.

Breathing and Cellular Respiration

The oxygen that arrives at the cells from the lungs is used by the cells to help release the energy stored in molecules of sugar. Cellular respiration is the process of breaking down glucose to release energy (see the *Cell Functions* chapter). The waste products of cellular respiration include carbon dioxide and water. The carbon dioxide molecules move out of the cells and into the capillaries that surround the cells. As explained above, the carbon dioxide is removed from the body by the lungs.

Lesson Summary

- Your respiratory system is made up of the tissues and organs that allow oxygen to enter and carbon dioxide to leave your body.
- Respiratory system organs include your nose, mouth, larynx, pharynx, lungs, and diaphragm.
- During inhalation, the diaphragm contracts and moves downward, and brings air into the lungs.

During exhalation, the diaphragm and rib muscles relax and air is pushed out of the lungs.

- Oxygen enters the lungs, then passes through the alveoli and into the blood. The oxygen is carried around the body in blood vessels.
- Carbon dioxide, a waste gas, moves into the blood capillaries and is brought to the lungs to be released into the air during exhalation.
- The oxygen that arrives from the lungs is used by the cells during cellular respiration to release the energy stored in molecules of sugar.

Review Questions

Recall

1. Name the five main organs in the respiratory system.
2. What is the main function of the respiratory system?
3. In what part of the lung does gas exchange occur?
4. What is the important gas that is carried into the lungs during inhalation?

Apply Concepts

5. A classmate says that lung muscles cause the lungs to move during breathing. Do you agree with your classmate?
6. How do the respiratory system and the cardiovascular system work together?
7. Breathing is an involuntary action. Does this mean that you cannot control your breathing?
8. What is the difference between breathing and respiration?
9. What is the name of the waste gas that is released during exhalation?

Critical Thinking

10. If a disease caused the alveoli to collapse, how might this affect a person's health?

Further Reading / Supplemental Links

- `http://en.wikipedia.org/wiki`

Points to Consider

- How do you think the health of your respiratory system might affect the health of other body systems?

8.2 Health of the Respiratory System

Lesson Objectives

- Identify the organs affected by a respiratory disease.
- Identify how a respiratory disease can affect the rest of the body.
- Describe how asthma affects breathing.
- Outline how smoking affects the respiratory system.
- Identify what you can do to keep your respiratory system healthy.

Check Your Understanding

- What is the role of the respiratory system?
- What are some of the organs in the respiratory system?

Vocabulary

allergen asthma
bronchitis chronic disease
chronic obstructive pulmonary disease (COPD) emphysema
environmental tobacco smoke (ETS) lifestyle disease
lung cancer pathogen
pneumonia respiratory disease
tuberculosis (TB)

Respiratory System Disease

Most of the time your respiratory system works well. But your respiratory system can sometimes be knocked out of homeostasis. Recall that homeostasis is the balancing act your body performs that keeps everything inside of your body stable. Anything that stops the respiratory system from doing its job disrupts homeostasis. When homeostasis is thrown out of balance, your respiratory system can get diseases. There are many causes of respiratory diseases, and many ways to treat such diseases.

In general, diseases that last a short time are called acute diseases. Other diseases can last for a long time, perhaps years. Diseases that last for a long time are called **chronic diseases**. Both acute and chronic diseases affect the respiratory system. **Respiratory diseases** are diseases of the lungs, bronchial tubes, trachea, nose, and throat (**Figure** 8.6). These diseases can range from a mild cold to a severe case of pneumonia. Respiratory diseases are common and may cause illness or death. Some respiratory diseases are caused by bacteria or viruses, while others are caused by environmental pollutants such as tobacco smoke. Some diseases can be genetic.

Bronchitis

Bronchitis is an inflammation of the bronchi, which means they become red and swollen with infection. Acute bronchitis is usually caused by viruses or bacteria, and may last several days or weeks. It is

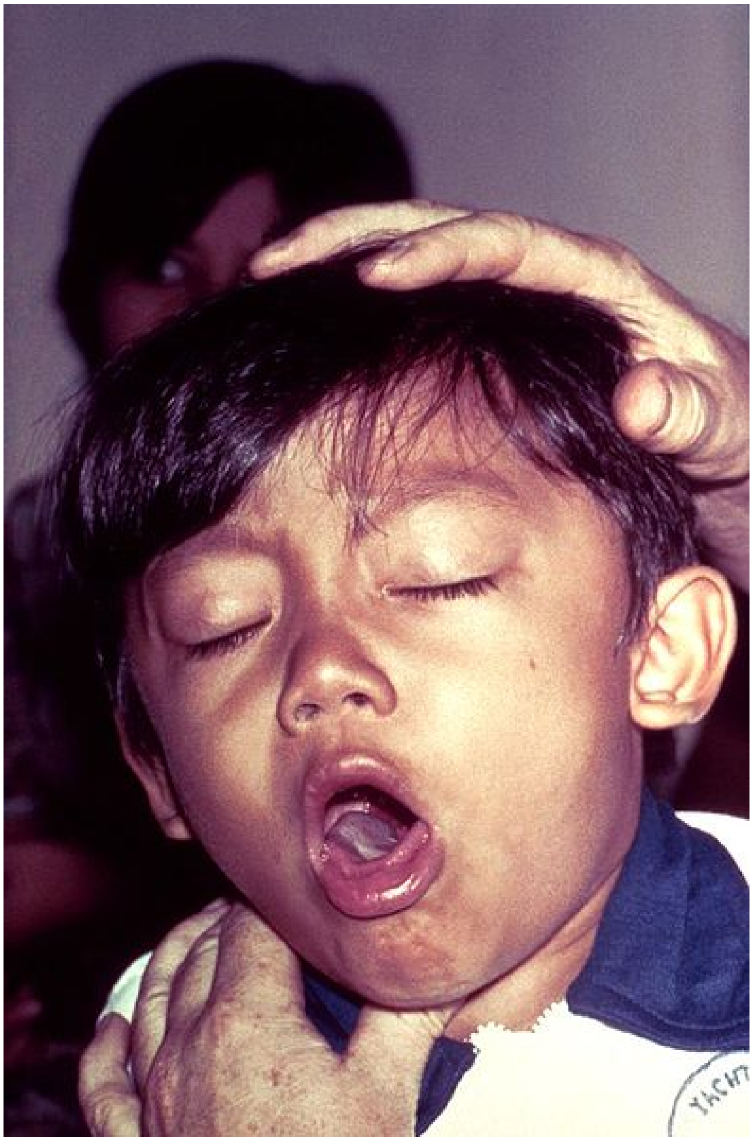


Figure 8.6: This boy is suffering from whooping cough (also known as pertussis), which gets its name from the loud whooping sound that is made when the person inhales during a coughing fit.

characterized by a cough that produces phlegm, or mucus. Symptoms include shortness of breath and wheezing. Acute bronchitis is usually treated with antibiotics.

Chronic bronchitis may not be caused by a bacterium or a virus. Chronic bronchitis occurs when a cough produces phlegm, for at least three months in a two-year period. Tobacco smoking is the most common cause of chronic bronchitis, but it can be caused by environmental pollution, such as smog and dust. It is generally part of a disease called chronic obstructive pulmonary disease (COPD). Treatments for bronchitis include antibiotics and steroid drugs used to reduce inflammation.

Asthma

Asthma is a chronic illness in which the bronchioles are inflamed and become narrow, as shown in **Figure** 8.7. The muscles around the bronchioles contract which narrows the airways. Large amounts of mucus are also made by the cells in the lungs. A person with asthma has difficulty breathing. Their chest feels tight and they wheeze. Asthma can be caused by different things, such as allergies. An **allergen** is any antigen that is not actually a disease, but your body responds to it as if it were a disease. Allergens can cause allergic reactions. Common allergens that cause asthma are mold, dust, or pet hair.

Asthma can also be caused by cold air, warm air, moist air, exercise, or stress. The most common asthma triggers are illnesses like the common cold. The symptoms of asthma can usually be controlled with medicine. Bronchodilators are drugs that reduce inflammation of the bronchioles and are often used to treat asthma. An inhaler is usually a bronchodilator.

Asthma is not contagious and cannot be passed on to other people. Children and adolescents who have asthma can still lead active lives if they control their asthma. Asthma can be controlled by taking medication and by avoiding contact with environmental triggers for asthma, like smoking.

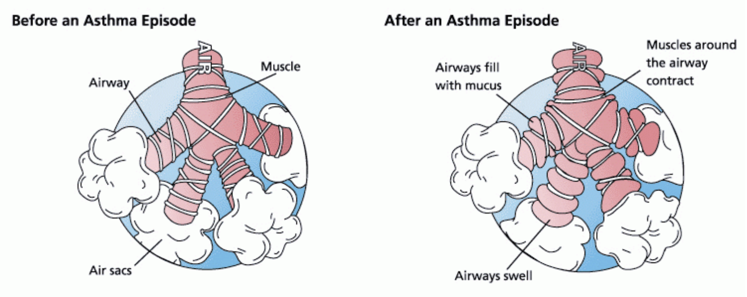


Figure 8.7: Asthma occurs when the bronchioles swell and the muscles around the bronchioles contract.

Pneumonia

Pneumonia is an illness that occurs when the alveoli become inflamed and filled with some kind of fluid. When a person has pneumonia, gas exchange cannot happen properly across the alveoli. Pneumonia can be caused by many things. Infection by bacteria, viruses, fungi, or parasites can cause pneumonia. An injury caused by chemicals or a physical injury to the lungs can also cause pneumonia. Symptoms of pneumonia include cough, chest pain, fever, and difficulty breathing. Treatment depends on the cause of pneumonia. Bacterial pneumonia is treated with antibiotics.

Pneumonia is a common illness that affects people in all age groups. It is a leading cause of death among the elderly and people who are chronically and terminally ill. Sometimes people take vaccines to prevent certain types of pneumonia.

Tuberculosis

Tuberculosis (TB) is a common and often deadly disease caused by a genus of bacterium called *Mycobacterium*. When a disease like TB can passed from person to person, it is called "infectious." Tuberculosis most commonly attacks the lungs, but can also affect other parts of the body. TB is a chronic disease, but most people who become infected do not develop the full disease.

The TB bacteria are spread in the air when people who have the disease cough, sneeze or spit, so it is very contagious. To help prevent the spread of the disease, public health notices, such as the one in **Figure** 8.8, remind people how to stop the spread of the disease.

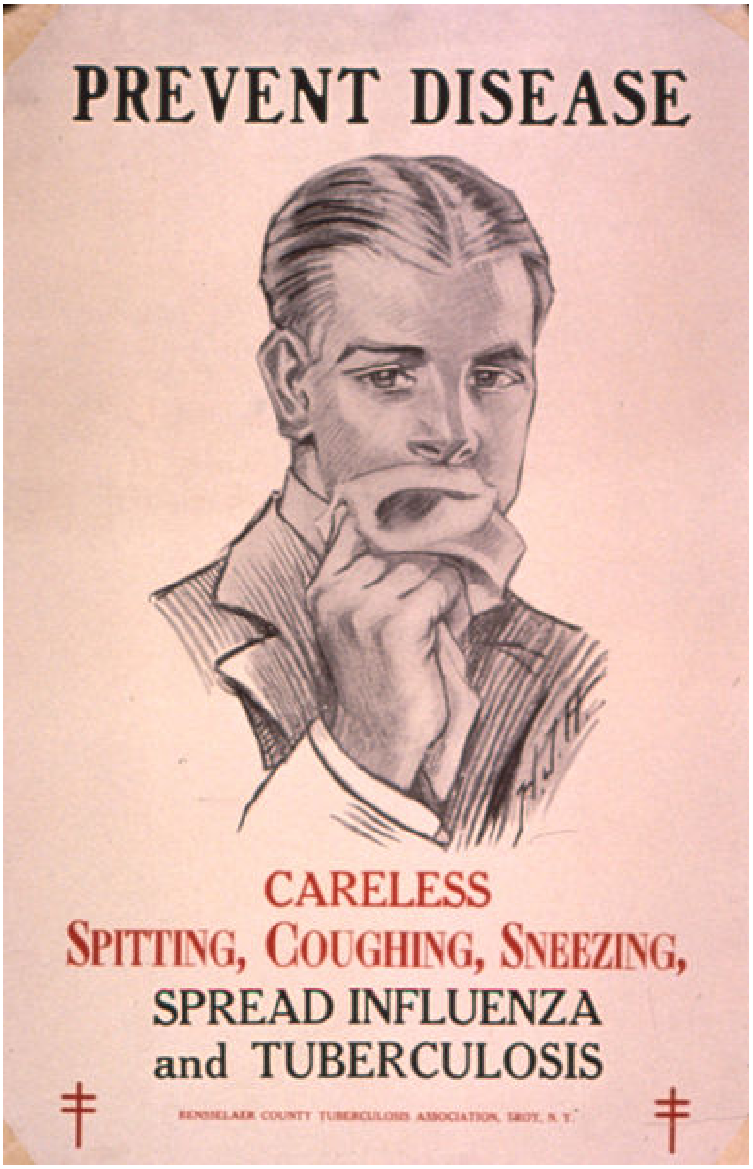

PREVENT DISEASE
CARELESS
SPITTING, COUGHING, SNEEZING,
SPREAD INFLUENZA
and TUBERCULOSIS
RENSSELAER COUNTY TUBERCULOSIS ASSOCIATION, TROY, N. Y.

Figure 8.8: A public health notice from the early 20th century reminded people that TB could be spread very easily.

Cancer

Lung cancer is a disease where the cells found in the lungs grow out of control. The growing mass of cells can form a tumor that pushes into nearby tissues. The tumor will affect how these tissues work. Lung cancer, which is the most common cause of cancer-related death in men and the second most common in women, is responsible for 1.3 million deaths worldwide every year (**Figure** 8.9). The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss. The most common cause of lung cancer is exposure to tobacco smoke.

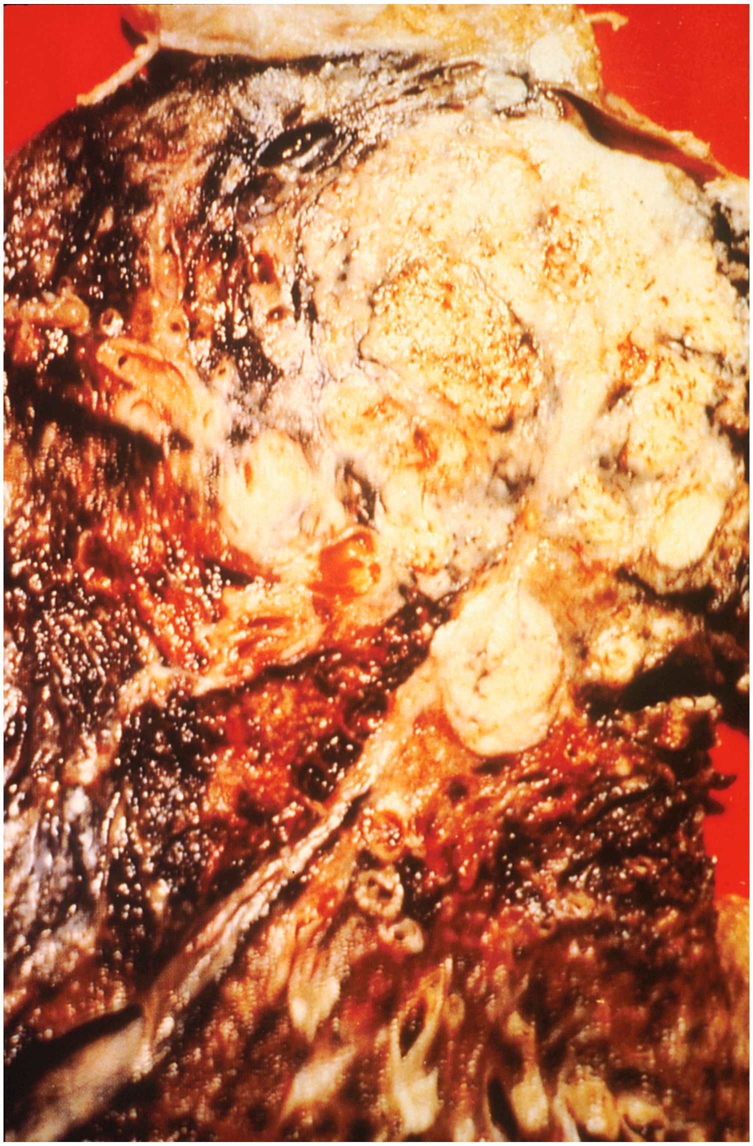


Figure 8.9: The inside of lung showing cancerous tissue.

Emphysema

Emphysema is a chronic lung disease caused by the breakdown of the lung tissue. The surfaces of healthy alveoli are springy and flexible. They stretch out a little when full of air and relax when air leaves them. But the breakdown of the tissues that support the alveoli and the capillaries that feed the alveoli cause the alveoli to become hard and stiff. Eventually, the walls of the alveoli break down and the alveoli become larger. When alveoli become larger, oxygen cannot enter the blood as it did before. Symptoms of emphysema include shortness of breath during exercise. Damage to the alveoli, which can be seen in **Figure** 8.10, is not curable. Smoking is the leading cause of emphysema.

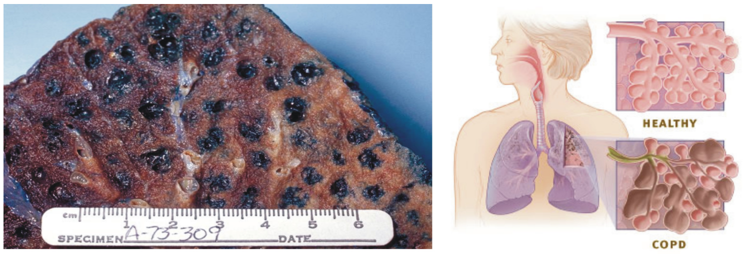


Figure 8.10: The lung of a smoker who had emphysema (left). The black areas are enlarged alveoli, and tar, a sticky, black substance found in tobacco smoke is evident. Chronic obstructive pulmonary disease (right), is a tobacco-related disease that is characterized by emphysema.

Causes of Respiratory Diseases

Pathogens

Many respiratory diseases are caused by pathogens. A **pathogen** is an organism that causes disease in another organism. Certain bacteria, viruses, and fungi are pathogens of the respiratory system. The common cold and flu are caused by viruses. The influenza virus that causes the flu is shown in **Figure** 8.11. Tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing, sneezing, and spitting.

Pollution

The quality of the air can affect the health of your lungs. Asthma, heart and lung diseases, allergies, and several types of cancers are all linked to air quality. Air pollution can be either outdoor pollution or indoor pollution. Outdoor air pollution can be caused by car exhaust fumes, smoke from factories and forest fires, volcanoes, and animal feces. These pollutants contain tiny particles that can get “stuck” in the tissues of the respiratory system and irritate the lungs. Indoor air pollution can be caused by tobacco smoke, dust, mold, insects, rodents, and cleaning chemicals.

Lifestyle Choices

Smoking is the major cause of chronic respiratory disease as well as cardiovascular disease and cancer. Exposure to tobacco smoke, by smoking or by breathing air that contains tobacco smoke, is the leading cause of preventable death in the U.S. Regular smokers die about 10 years earlier than nonsmokers do. The Centers for Disease Control and Prevention (CDC) describes tobacco use as ”the single most important preventable risk to human health in developed countries and an important cause of [early] death worldwide.”

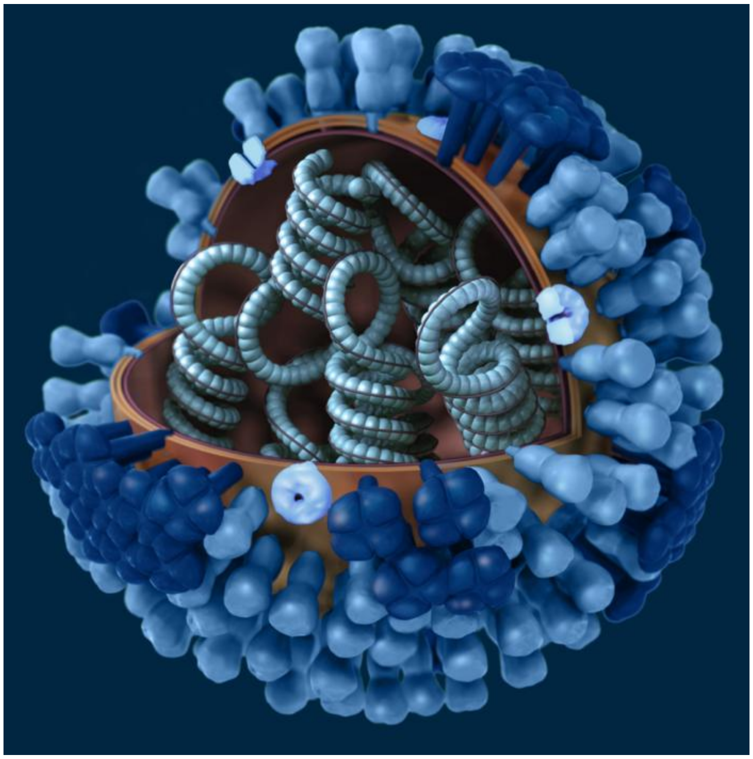


Figure 8.11: This is the influenza virus that causes the swine flu, or H1N1. The Center for Disease Control and Prevention recommends that children between the ages of 6 months and 19 years get a flu vaccination each year.

Dangers of Smoking

Tobacco use, particularly cigarette smoking, is a preventable cause of death in the United States. This means that people would not die if they stopped smoking. Cigarette smoking alone is directly responsible for approximately 30 percent of all yearly cancer deaths in the United States. The main health risks of using tobacco are linked to diseases of the cardiovascular system and respiratory system. Cardiovascular diseases caused by smoking include heart disease and stroke.

Diseases of the respiratory system that are caused by exposure to tobacco smoke include:

- Emphysema.
- Lung cancer.
- Cancers of the larynx and mouth.

Cigarette smoking causes 87 percent of lung cancer deaths. Smoking and using tobacco is also linked to the risk of developing other types of cancer, such as pancreatic and stomach cancer.

Indoor Air Pollution

Cigarettes, like the ones shown in **Figure** 8.12, are a major source of indoor air pollution. Cigarette smoke contains about 4,000 substances, including over 60 cancer-causing chemicals. Many of these substances, such as carbon monoxide, tar, arsenic, and lead, are toxic to the body. Non-smokers can also be affected by tobacco smoke. Exposure to secondhand smoke, also known as **environmental tobacco smoke (ETS)**, greatly increases the risk of lung cancer and heart disease in nonsmokers.

Figure 8.12: Tobacco use, particularly cigarette smoking, is the single most preventable cause of death in the United States.

Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) is a disease of the lungs that occurs when the airways narrow and air cannot enter the lungs as well as it did before. This leads to shortness of breath.

The lack of air entering the lungs usually gets worse over time. COPD is most commonly caused by smoking. Gases and particles in tobacco smoke trigger an inflammatory response in the lung. The inflammatory response in the larger airways is known as chronic bronchitis. In the alveoli, the inflammatory response causes the breakdown of the tissues in the lungs, leading to emphysema.

Keeping Your Respiratory System Healthy

Many of the diseases related to smoking are called **lifestyle diseases**, diseases that are caused by choices that people make in their daily lives. For example, the choice to smoke can lead to cancer in later life. But there are many things you can do to help keep your respiratory system healthy.

Avoid Smoking

Never smoking or quitting now are the most effective ways to reduce your risk of developing chronic respiratory diseases, such as cancer.

Eat Well, Exercise Regularly, and Get Rest

Eating a healthful diet, getting enough sleep, and being active every day can help keep your immune system strong.

Wash Your Hands

Washing your hands often, and after sneezing, coughing or blowing your nose, helps to protect you and others from diseases. Washing your hands for 20 seconds with soap and warm water can help prevent colds and flu.

Some viruses and bacteria can live from 20 minutes up to 2 hours or more on surfaces like cafeteria tables, doorknobs, and desks. A public health notice that shows people how to prevent the spread of respiratory diseases is shown in **Figure** 8.13.

Avoid Contact with Others When Sick

Do not go to school or to other public places when you are sick. You risk spreading your illness to other people and getting sicker, if you catch something else.

Visit Your Doctor

Getting the recommended vaccinations can help prevent diseases such as whooping cough and flu. Seeking medical help for diseases such as asthma can help stop the disease from getting worse.

Lesson Summary

- Respiratory diseases are diseases that affect the lungs, bronchial tubes, trachea, nose, and throat.
- Respiratory diseases can reduce the amount of oxygen that gets into the blood.
- Asthma is an illness that occurs when the bronchioles are inflamed and become narrow.

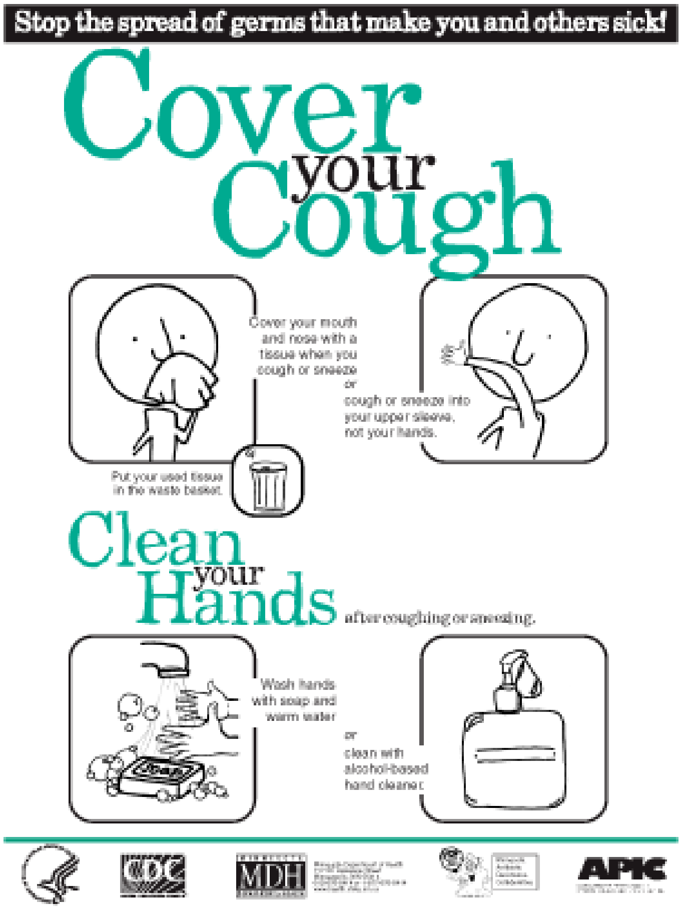

Stop the spread of germs that make you and others sick!
Cover your Cough
Cover your mouth and nose with a tissue when you cough or sneeze
or
cough or sneeze into your upper sleeve, not your hands.
Put your used tissue in the waste basket.
Clean your Hands after coughing or sneezing.
Wash hands with soap and warm water
or
clean with alcohol-based hand cleaner.
Soap
CDC
MDH
APIC

Figure 8.13: Cover your Cough - Clean your Hands is a public health campaign that reminds people of the quickest and easiest ways to avoid spreading respiratory diseases such as colds and the flu.

- Difficulty breathing happens because of the inflammation, contraction of the muscles, and the production of mucus by the cells that line the bronchioles.
- Diseases of the respiratory system that are caused by exposure to tobacco smoke include emphysema, lung cancer and cancers of the larynx and mouth.
- Cigarette smoking causes 87 percent of lung cancer deaths.
- Avoid smoking, get enough exercise, and wash your hands in order to protect your respiratory system from illness.

Review Questions

Recall

1. Identify two organs that can be affected by respiratory diseases.
2. What lifestyle activity has the largest health impact on the respiratory system?
3. Identify three diseases caused by smoking.
4. Identify three things besides smoking that can cause a respiratory disease.
5. What are two things you can do to keep your respiratory system healthy?

Apply Concepts

6. How might a respiratory disease affect the rest of the body?
7. How does asthma affects the bronchioles?
8. Explain how washing your hands can help prevent you from catching a cold.

Critical Thinking

9. Pneumonia is a disease that causes the alveoli to fill up with fluid. How might this affect the lungs' ability to absorb oxygen?

10. A person who has never smoked before gets lung cancer. How might they have contracted the disease?

Further Reading / Supplemental Links

- `http://www.cdc.gov/vaccines/vpd-vac/pertussis/default.htm`
- `http://www.cdc.gov//HealthyLiving/`
- `http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer` `http://en.wikipedia.org/wiki/Cigarette_smoking;` `http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer`
- `http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer`
- `http://www.cdc.gov/flu/protect/covercough.htm`

Points to Consider

Next, we move on to the excretory system.

- The excretory system gets rids of a certain type of waste. What type of waste do you think is removed by this system?

8.3 The Excretory System

Lesson Objectives

- Identify the functions of the excretory system.
- List the organs of the excretory system.
- Describe the parts of urinary system.
- Outline how the kidneys filter blood.
- Identify three disorders of the urinary system.

Check Your Understanding

- What are some ”wastes” that must be removed from your body?
- Do your circulatory and respiratory systems remove ”waste?”

Vocabulary

excretion excretory system kidney
kidney dialysis kidney failure nephron
urinary bladder urinary system urinary tract infection (UTI)
urination urine

The Excretory System

One of the most important ways your body maintains homeostasis is by keeping the right amount of water and salts inside your body. If you have too much water in your body, your cells can swell and burst. If you have too little water in your body, your cells can shrivel up like an old apple. Either extreme can cause illness and death of cells, tissues, and organs. The organs of your **excretory system** help to keep the correct balance of water and salts within your body.

Your body also needs to remove the wastes that build up from cell activity and from digestion. These wastes include carbon dioxide, urea, and certain plant materials. If these wastes are not removed, your cells can stop working and you can get very sick. The excretory system can also help to release wastes from the body. **Excretion** is the process of removing wastes from the body.

The organs of the excretory system are also parts of other organ systems. For example, your lungs are part of the respiratory system. Your lungs remove carbon dioxide from your body, so they are also part of the excretory system. More organs of the excretory system are listed in **Table ??**.

Table 8.1: **Organs of the Excretory System**

Organ(s)	Function	Other Organ System of which it is Part
Lungs	Remove carbon dioxide	Respiratory system
Skin	Sweat glands remove water, salts, and other wastes	Integumentary system

Table 8.1: (continued)

Organ(s)	Function	Other Organ System of which it is Part
Large intestine	Removes solid waste and some water in the form of feces	Digestive system
Kidneys	Remove urea, salts, and excess water from the blood	Urinary system

Table 19.4: Organs of the Excretory System

Functions of the Excretory System

The excretory system controls the levels of water and salts in your body by removing wastes. This means the excretory system has an important role in maintaining homeostasis. Your body takes nutrients from food and uses them for energy, growth, and repair. After your body has taken what it needs from the food, waste products are left behind in the blood and in the large intestine. These waste products need to be removed from the body. The kidneys work with the lungs, skin, and intestines to keep the correct balance of nutrients, salts and water in your body.

The Urinary System

Sometimes, the urinary system is called the excretory system. But the urinary system is only one part of the excretory system. Recall that the excretory system is made up of the skin, lungs, and large intestine as well as the kidneys. The **urinary system** is the organ system that makes, stores, and gets rid of urine. It includes:

- Two kidneys.
- Two ureters.
- One bladder.
- One urethra.

The urinary system is shown in **Figure** 8.14.

Organs of the Urinary System

1. As you can see from **Figure** 8.14, the kidneys are two bean-shaped organs. **Kidneys** filter and clean the blood and form urine. They are about the size of your fists and are found near the middle of the back, just below your rib cage.
2. Ureters are tube-shaped and bring urine from the kidneys to the urinary bladder.
3. The **urinary bladder** is a hollow and muscular organ. It is shaped a little like a balloon. It is the organ that collects urine.
4. Urine leaves the body through the urethra.

What is Urine?

Urine is a liquid that is formed by the kidneys when they filter wastes from the blood. Urine contains mostly water, but also contains salts and nitrogen-containing molecules. The amount of urine released

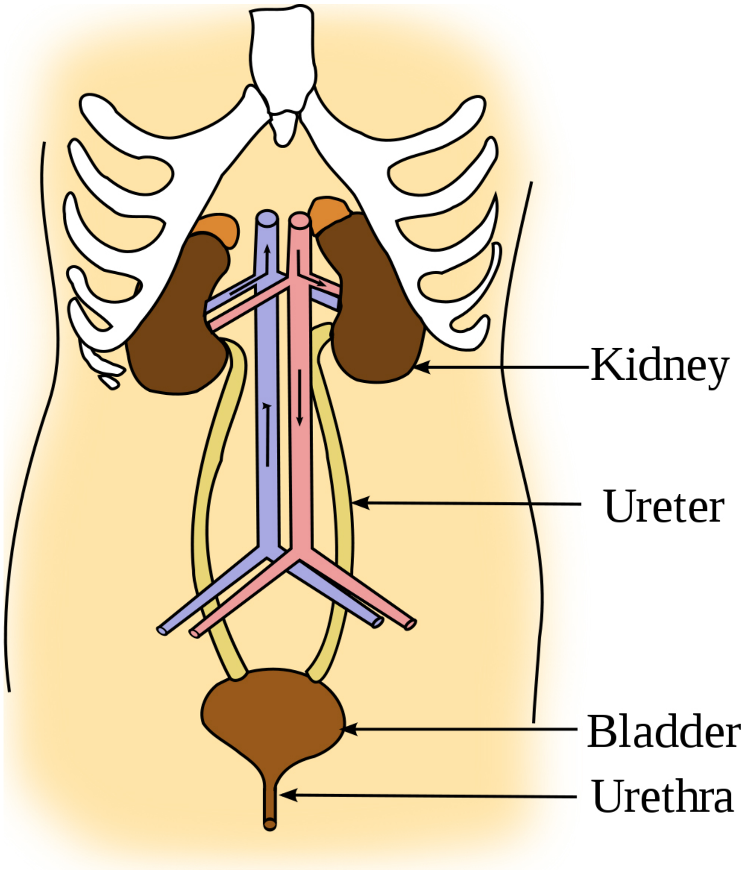


Figure 8.14: The kidneys filter the blood that passes through them and the urinary bladder stores the urine until it is released from the body.

from the body depends on many things. Some of these include the amounts of fluid and food a person consumes and how much fluid they have lost from sweating and breathing. Urine ranges from colorless to dark yellow, but is usually a pale yellow color. Light yellow urine contains mostly water. The darker the urine, the less water it contains.

The urinary system also removes a type of waste called *urea* from your blood. Urea is a nitrogen-containing molecule that is made when foods containing protein, such as meat, poultry, and certain vegetables, are broken down in the body. Urea and other wastes are carried in the bloodstream to the kidneys, where they are removed and form urine.

How the Kidneys Filter Wastes

The kidneys are important organs in maintaining homeostasis. Kidneys perform a number of homeostatic functions.

- They maintain the volume of body fluids.
- They maintain the balance of salt ions in body fluids.
- They excrete harmful nitrogen-containing molecules, such as urea, ammonia, and uric acid.

There are many blood vessels in the kidneys, as you can see in **Figure** 8.15. The kidneys remove urea from the blood through tiny filtering units called nephrons. **Nephrons** are tiny, tube-shaped structures found inside each kidney. A nephron is shown in **Figure** 8.16. Each kidney has up to a million nephrons. Each nephron collects a small amount of fluid and waste from a small group of capillaries.

If the body is in need of more water, water is removed from the fluid inside the nephron and is returned to the blood. The fluid within nephrons is carried out into a larger tube in the kidney called a ureter, which you can see in **Figure** 8.16. Urea, together with water and other wastes, forms the urine as it passes through the nephrons and the kidney.

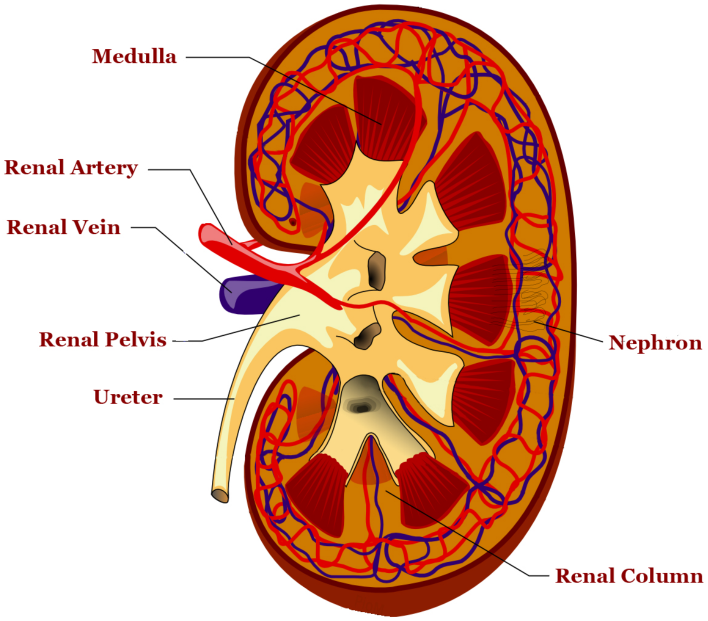


Figure 8.15: Structures of the kidney; fluid leaks from the capillaries and into the nephrons where the fluid forms urine then moves to the ureter and on to the bladder.

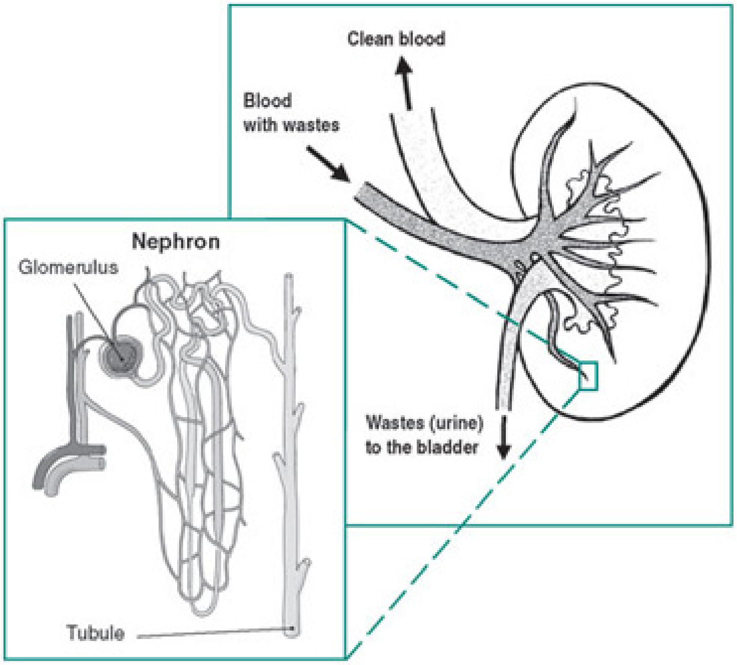


Figure 8.16: The location of nephrons in the kidney. The fluid collects in the nephron tubules, and moves to the bladder through the ureter.

Formation of Urine

The process of urine formation is as follows:

1. Blood flows into the kidney through the renal artery, shown in **Figure** 8.16. The renal artery connects to capillaries inside the kidney. Capillaries and nephrons lie very close to each other in the kidney.
2. The blood pressure within the capillaries causes water, salts, sugars, and urea to leave the capillaries and move into the nephron.
3. The water and salts move along through the tube-shaped nephron to a lower part of the nephron.
4. The fluid that remains in the nephron at this point is called urine.
5. The blood that leaves the kidney in the renal vein has much less waste than the blood that entered the kidney.
6. The urine is collected in the ureters and is moved to the urinary bladder, where it is stored.

Nephrons filter about ¼ cup of body fluid per minute. In a 24-hour period, nephrons filter 180 liters of fluid, and 1.5 liters of the fluid is released as urine. Urine enters the bladder through the ureters. Similar to a balloon, the walls of the bladder are stretchy. The stretchy walls allow the bladder to hold a large amount of urine. The bladder can hold about 1½ to 2½ cups of urine, but may also hold more if the urine cannot be released immediately.

How do you know when you have to urinate? **Urination** is the process of releasing urine from the body. Urine leaves the body through the urethra. Nerves in the bladder tell you when it is time to urinate. As the bladder first fills with urine, you may notice a feeling that you need to urinate. The urge to urinate becomes stronger as the bladder continues to fill up.

Brain Control

The kidneys never stop filtering waste products from the blood, so they are always producing urine. The amount of urine your kidneys produce is dependent on the amount of fluid in your body. Your body loses water through sweating, breathing, and urination. The water and other fluids you drink every day help to replace the lost water. This water ends up circulating in the blood because blood plasma is mostly water.

The filtering action of the kidneys is controlled by the pituitary gland. The pituitary gland is about the size of a pea and is found below the brain, as shown in **Figure** 8.17. The pituitary gland is also part of the endocrine system. The pituitary gland releases hormones, which help the kidneys to filter water from the blood.

The movement of water back into blood is controlled by a hormone called antidiuretic hormone (ADH). ADH is released from the pituitary gland in the brain. One of the most important roles of ADH is to control the body's ability to hold onto water. If a person does not drink enough water, ADH is released. It causes the blood to reabsorb water from the kidneys. If the kidneys remove less water from the blood, what will the urine look like? It will look darker, because there is less water in it.

When a person drinks a lot of water, then there will be a lot of water in the blood. The pituitary gland will then release a lower amount of ADH into the blood. This means less water will be reabsorbed by the blood. The kidneys then produce a large volume of urine. What color will this urine be?

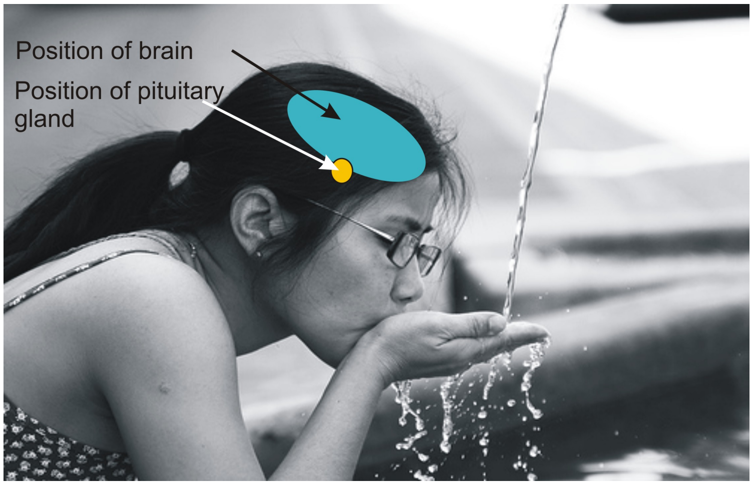


Figure 8.17: The pituitary gland is found directly below the brain and releases hormones that control how urine is produced.

Excretory System Problems

The urinary system controls the amount of water in the body and removes wastes. Any problem with the urinary system can also affect many other body systems.

Kidney Stones

In some cases, certain mineral wastes can form kidney stones, like the one shown in **Figure** 8.18. Stones form in the kidneys and may be found anywhere in the urinary system. They vary in size. Some stones cause great pain, while others cause very little pain. Some stones may need to be removed by surgery or ultrasound treatments.

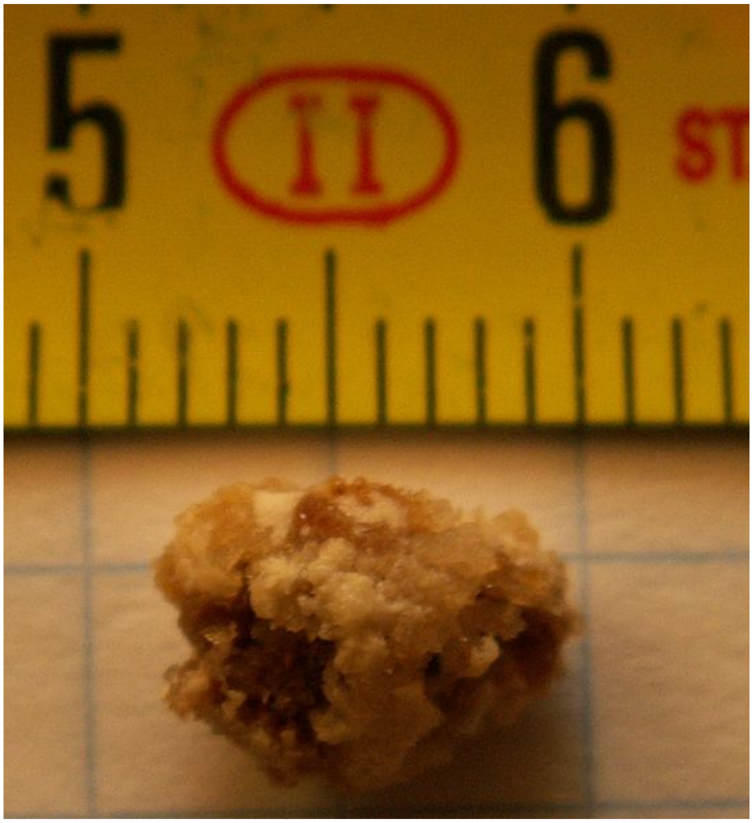


Figure 8.18: A kidney stone. The stones can form anywhere in the urinary system.

Kidney failure

Kidney failure happens when the kidneys cannot remove wastes from the blood. If the kidneys are unable to filter wastes from the blood, the wastes build up in the body. Homeostasis is disrupted because the fluids in the body are out of balance. Kidney failure can be caused by an accident that injures the kidneys, the loss of a lot of blood, or by some drugs and poisons. Kidney failure may lead to permanent loss of kidney function. But if the kidneys are not seriously damaged, they may recover.

Chronic kidney disease is the slow decrease in kidney function that may lead to permanent kidney failure. A person who has lost kidney function may need to get kidney dialysis. **Kidney dialysis** is the process of filtering the blood of wastes using a machine. A dialysis machine (also called a hemodialyzer) filters the blood of waste by pumping it through a fake kidney. The filtered blood is then returned to the patient's body. A dialysis machine is shown in **Figure** 8.19.

Urinary tract infections (UTIs)

Urinary tract infections (UTIs) are bacterial infections of any part of the urinary tract. When bacteria get into the bladder or kidney and produce more bacteria in the urine, they cause a UTI. The most common type of UTI is a bladder infection. Women get UTIs more often than men. UTIs are often treated with antibiotics.

Figure 8.19: During dialysis, a patient's blood is sent through a filter that removes waste products. The clean blood is returned to the body.

Lesson Summary

- The excretory system controls the chemical make-up of liquids found in the body.
- The organs of the excretory system remove wastes. They also maintain the proper levels of water, salts, and nutrients in the body.
- The lungs, skin, kidneys, and large intestine are all organs in the excretory system.
- The urinary system is made up of the kidneys, the ureters, the bladder, and the urethra.
- The filtering parts of the kidneys are the nephrons.
- Water and waste molecules move out of the blood capillaries and into the nephrons. Most of the water returns to the blood.
- Urine collects in the nephron and moves to the urinary bladder through the ureters.
- The filtering action of the kidneys is controlled by the pituitary gland.
- ADH is the hormone released by the pituitary gland and controls the how water is reabsorbed by the blood from the kidneys.
- Disorders of the urinary system include kidney stones, kidney disease, and urinary tract infections.

Review Questions

Recall

1. What is the main function of the excretory system?

2. List the organs that make up the excretory system.

3. What is urine made of?

4. What is the purpose of the urinary bladder?

5. What connects the kidneys to the urinary bladder?

Apply Concepts

6. What is the difference between the urinary system and the excretory system?

7. How do the kidneys filter the blood?

8. The walls of the urinary bladder are stretchy. What do you think is the advantage of having these stretchy walls?

9. What does antidiuretic hormone (ADH) do?

10. What is a urinary tract infection?

11. Why is kidney failure such a serious health problem?

Critical Thinking

12. If a person's urine is dark brown, what are two organs in the body that might not be functioning properly? Explain what might be wrong with the two organs.

Further Reading / Supplemental Links

- `http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookEXCRETE`

- http://kidney.niddk.nih.gov/kudiseases/pubs/yourkidneys
- http://en.wikipedia.org/wiki/Kidney_function

Points to Consider

Next we turn our attention to the nervous system.

- What do you think the nervous system is? What do you think it does?

Image Sources

(1) Robert R. Wal. http://en.wikipedia.org/wiki/Image:Nefrolit.jpg. Public Domain.

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(3) Mr TS88 Duel. http://commons.wikimedia.org/wiki/File:Alveoli.svg. GNU-FDL, CC-BY-2.5.

(4) http://commons.wikimedia.org/wiki/File:Centrilobular_emphysema_865_lores.jpg. (b)Public Domain, COPD.

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(17) Theresa Knott. *system.svg* . CC-BY-SA 2.5.

(18) http://www.cdc.gov/flu/images/CoverCgh-Sch-view.gif. (b)Public Domain.

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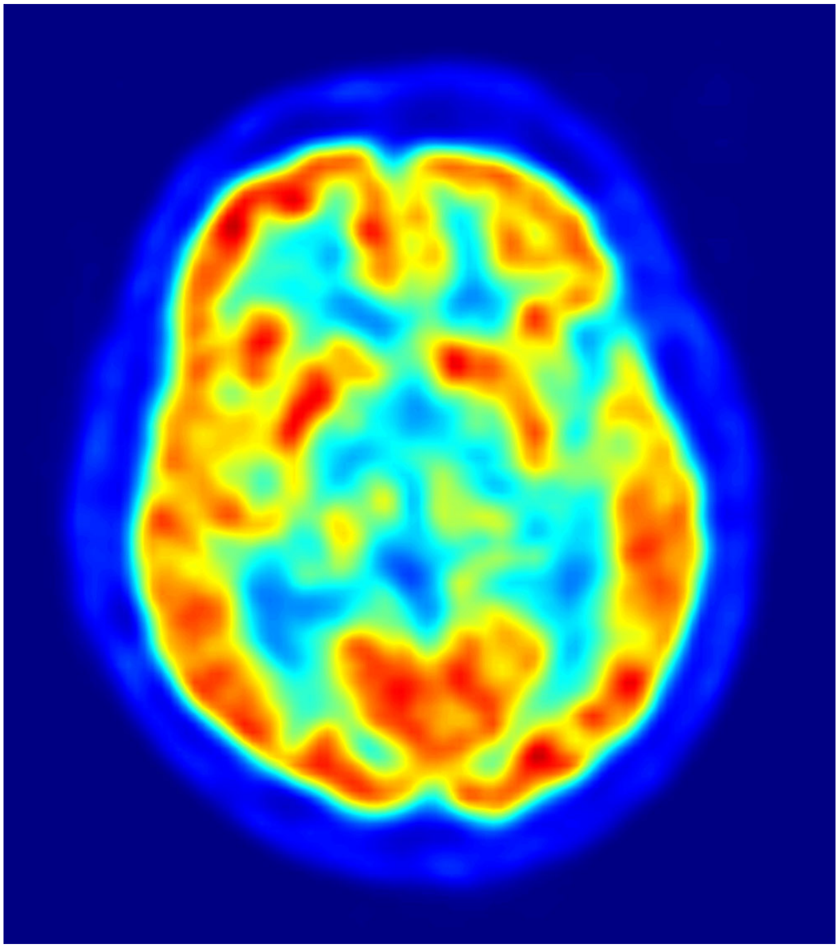
Chapter 9

MS Controlling the Body



The above image shows a PET scan of a human brain. A PET scan is a recently created technological tool that allows scientists to see activity in the brain. The red and yellow spots are the most active parts of the brain.

But if one part of the brain is more active than another, what does that mean? Are there different parts of the brain? Do they have different jobs? The brain controls all body functions, including ones you cannot control, like digestion, and ones you can control, like texting on a cellphone. But how does it control every function when it sits in your skull on top of your body?

Does the brain send messages to other parts of your body? What does a ”message” in your body look like?

Additionally, what would it mean if there were few active parts in the above brain scan? Would a person’s brain be functioning properly? What kind of diseases can cause brain damage?

Consider these questions about the brain as you read about the system that controls all other body systems, the nervous system.

9.1 The Nervous System

Lesson Objectives

- Identify the functions of the nervous system.
- Describe neurons and explain how they carry nerve impulses.
- Describe the structures of the central nervous system.
- Outline the divisions of the peripheral nervous system.

Check Your Understanding

- If groups of cells are called tissues and groups of tissues are called organs, what are groups of organs called?
- What are examples of human organ systems?
- Which organ system controls all the others?

Vocabulary

autonomic nervous system axon brain
brain stem cell body central nervous system
cerebellum cerebrum dendrite
motor division motor neuron nerve
nerve impulse nervous system neuron
neurotransmitter parasympathetic division peripheral nervous system
sensory division sensory neuron somatic nervous system
spinal cord sympathetic division synapse

What Does the Nervous System Do?

Groups of organs are called organ systems. Examples of human organ systems are the skeletal, digestive, and respiratory systems. The nervous system controls all the others.

Michelle was riding her scooter when she hit a hole in the street and started to lose control. She thought she would fall, but in the blink of an eye, she shifted her weight and kept her balance. Her heart was pounding, but at least she didn’t get hurt. How was she able to react so quickly? Michelle can thank her nervous system for that (**Figure** 9.1).

The **nervous system** controls all of the systems of the body. Controlling muscles and maintaining balance are just two of its roles. The nervous system also lets you:

Figure 9.1: Staying balanced when riding a scooter requires control over the body's muscles. The nervous system controls the muscles and maintains balance.

- Sense your surroundings with your eyes and other sense organs.
- Sense the environment inside of your body, including temperature.
- Control your internal body systems and keep them in balance.
- Prepare your body to fight or flee in an emergency.
- Think, learn, remember, and use language.

The nervous system works by sending and receiving electrical signals. The signals are carried by nerves in the body, similar to the wires that carry electricity all over a house. For example, when Michelle started to fall off her scooter, her nervous system sensed that she was losing her balance. It responded by sending messages to muscles in her body. Some muscles tightened while others relaxed. As a result, Michelle's body became balanced again. How did her nervous system do all that in a split second? To answer this question, you need to know how the nervous system carries messages.

Neurons and Nerve Impulses

The nervous system is made up of nerves. A **nerve** is a bundle of nerve cells. A nerve cell that carries messages is called a **neuron** (**Figure** 9.2). The messages carried by neurons are called **nerve impulses**. Nerve impulses can travel very quickly because they are electrical impulses.

Think about flipping on a light switch when you enter a room. When you flip the switch, the electricity flows to the light through wires inside the walls. The electricity may have to travel many meters to reach the light, but the light still comes on as soon as you flip the switch. Nerve impulses travel just as fast through the network of nerves inside the body.

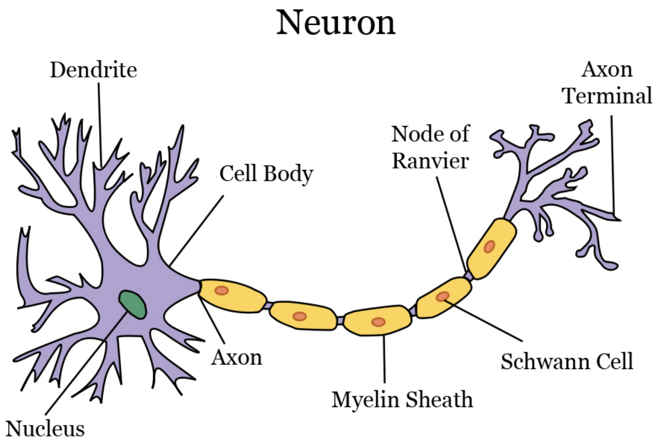


Figure 9.2: The axons of many neurons, like the one shown here, are covered with a fatty layer called myelin sheath. The sheath covers the axon, like the plastic covering on an electrical wire, and allows nerve impulses to travel faster along the axon.

What Does a Neuron Look Like?

A neuron has a special shape that lets it pass signals from one cell to another. As shown in **Figure** 9.2, a neuron has three main parts:

1. The cell body.
2. Many dendrites.

3. One axon.

The **cell body** contains the nucleus and other organelles. Dendrites and axons connect to the cell body, similar to rays coming off of the sun. **Dendrites** receive nerve impulses from other cells. **Axons** pass the nerve impulses on to other cells. A single neuron may have thousands of dendrites, so it can communicate with thousands of other cells.

Types of Neurons

Neurons are usually classified based on the role they play in the body. Two main types of neurons are sensory neurons and motor neurons.

- **Sensory neurons** carry nerve impulses from sense organs and internal organs to the central nervous system.
- **Motor neurons** carry nerve impulses from the central nervous system to organs, glands, and muscles - the opposite direction.

Both types of neurons work together. Sensory neurons carry information about the environment found inside or outside of the body to the central nervous system. The central nervous system uses the information to send messages through motor neurons to tell the body how to respond to the information.

The Synapse

The place where the axon of one neuron meets the dendrite of another is called a **synapse**. Synapses are also found between neurons and other type of cells, such as muscle cells. The axon of the sending neuron does not actually touch the dendrite of the receiving neuron. There is a tiny gap between them, the synapse, as shown in **Figure** 9.3.

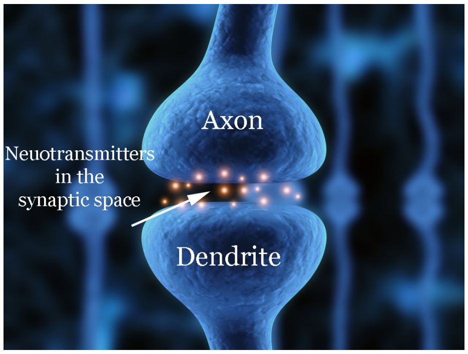


Figure 9.3: This diagram shows a synapse between neurons. When a nerve impulse arrives at the end of the axon, neurotransmitters are released and travel to the dendrite of another neuron, carrying the nerve impulse from one neuron to the next.

The following steps describe what happens when a nerve impulse reaches the end of an axon.

1. When a nerve impulse reaches the end of an axon, the axon releases chemicals called **neurotransmitters**.
2. Neurotransmitters travel across the synapse between the axon and the dendrite of the next neuron.
3. Neurotransmitters bind to the membrane of the dendrite.

4. The binding allows the nerve impulse to travel through the receiving neuron.

Did you ever watch a relay race? After the first runner races, he or she passes the baton to the next runner, who takes over. Neurons are a little like relay runners. Instead of a baton, they pass neurotransmitters to the next neuron. Examples of neurotransmitters are chemicals such as serotonin, dopamine, and adrenaline.

You can watch an animation of nerve impulses and neurotransmitters at: `http://www.mind.ilstu.edu/curriculum/neurons_intro/neurons_intro.php`.

Some people have low levels of the neurotransmitter called serotonin in their brain. Scientists think that this is one cause of depression. Medications called antidepressants help bring serotonin levels back to normal. For many people with depression, antidepressants control the symptoms of their depression and help them lead happy, productive lives.

The Central Nervous System

The **central nervous system (CNS)** is the largest part of the nervous system. As shown in **Figure** 9.4, it includes the brain and the spinal cord. The bony skull protects the brain. The spinal cord is protected within the bones of the spine, which are called vertebrae.

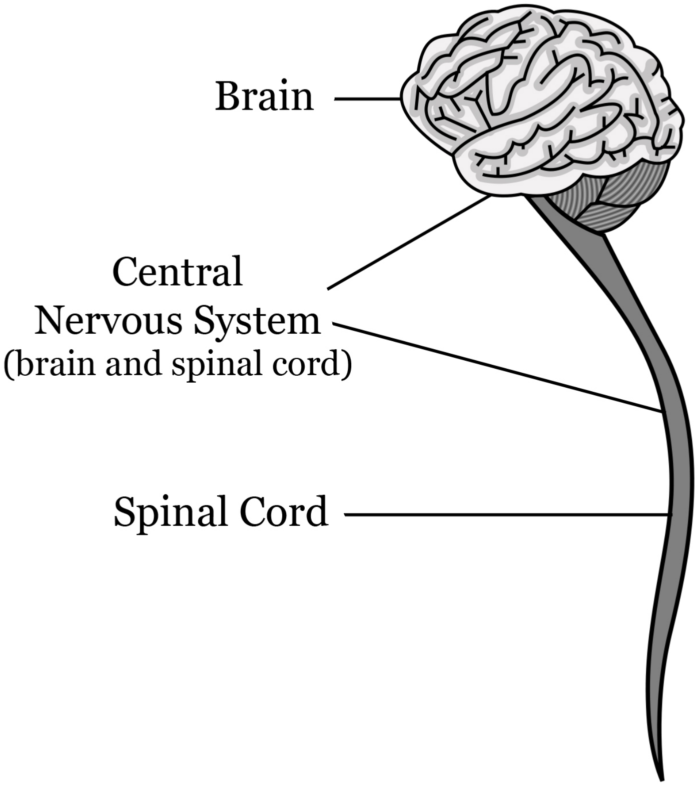


Figure 9.4: The brain and spinal cord make up the central nervous system.

The Brain

What weighs about 3 pounds and contains up to 100 billion cells? The answer is the human brain. The **brain** is the control center of the nervous system. It's like the pilot of a plane. It tells other parts of the nervous system what to do.

The brain is also the most complex organ in the body. Each of its 100 billion neurons has synapses connecting it with thousands of other neurons. All those neurons use a lot of energy. In fact, the adult brain uses almost a quarter of the total energy used by the body. The developing brain of a baby uses an even greater amount of the body's total energy.

The brain is the organ that lets us understand what we see, hear, or sense in other ways. It also allows us to learn, think, remember, and use language. The brain controls the organs in our body and our movements as well. As shown in **Figure** 9.5, the brain consists of three main parts, the cerebrum, the cerebellum and the brain stem.

1. The **cerebrum** is the largest part of the brain. It sits on top of the brain stem. The cerebrum controls functions that we are aware of, such as problem-solving and speech. It also controls voluntary movements, like waving to a friend. Whether you are doing your homework or jumping hurdles, you are using your cerebrum.
2. The **cerebellum** is the next largest part of the brain. It lies under the cerebrum and behind the brain stem. The cerebellum controls body position, coordination, and balance. Whether you are riding a bicycle or writing with a pen, you are using your cerebellum.
3. The **brain stem** is the smallest of the three main parts of the brain. It lies directly under the cerebrum. The brain stem controls basic body functions such as breathing, heartbeat, and digestion. The brain stem also carries information back and forth between the cerebrum and spinal cord.

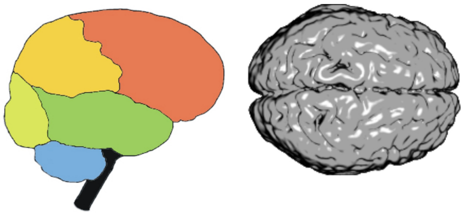


Figure 9.5: Side view of the brain. Can you find the locations of the three major parts of the brain?

The cerebrum is divided into a right and left half, as shown in **Figure** 9.5. Each half of the cerebrum is called a hemisphere. The two hemispheres are connected by a thick bundle of axons called the corpus callosum. It lies deep inside the brain and carries messages back and forth between the two hemispheres.

Did you know that the right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body? By connecting the two hemispheres, the corpus callosum allows this to happen.

> Dr. Jill Bolte Taylor is a brain scientist. At the age of 37, she suffered massive brain damage when blood vessels burst inside her brain. It took Dr. Taylor almost ten years to recover from the damage to her brain. She had to relearn even basic skills, like walking and talking. To share her story of recovery with others, Dr. Taylor wrote a popular book describing what she went through. Her story gave other people so much inspiration that *Time Magazine* named her one of the world's 100 most influential people in 2008.

Each hemisphere of the cerebrum is divided into four parts, called lobes. The four lobes are the:

1. Frontal.
2. Parietal.
3. Temporal.

4. Occipital.

Each lobe has different jobs. Some of the functions are listed in **Table** 9.1.

Table 9.1: **Cerebral Lobes and Their Functions**

Lobe	Main Function(s)
Frontal	Speech, thinking, touch
Parietal	Speech, taste, reading
Temporal	Hearing, smell
Occipital	Sight

The Spinal Cord

The **spinal cord** is a long, tube-shaped bundle of neurons. It runs from the brain stem to the lower back. The main job of the spinal cord is to carry nerve impulses back and forth between the body and brain. The spinal cord is like a two-way highway. Messages about the body, both inside and out, pass through the spinal cord to the brain. Messages from the brain pass in the other direction through the spinal cord to tell the body what to do.

The Peripheral Nervous System

There are other nerves in your body that are not found in the brain or spinal cord. The **peripheral nervous system (PNS)** contains all the nerves in the body that are found outside of the central nervous system. The network of nerves that make up the peripheral system is shown in **Figure** 9.6. They include nerves of the hands, arms, feet, legs, and trunk. They also include nerves of the scalp, neck, and face. Nerves that send and receive messages to the internal organs are also part of the peripheral nervous system.

The peripheral nervous system is divided into two parts, the sensory division and the motor division. How these divisions of the peripheral nervous system are related to the rest of the nervous system is shown in **Figure** 9.7. Refer to the figure as you read more about the peripheral nervous system below.

The Sensory Division

The **sensory division** carries messages from sense organs and internal organs to the central nervous system. Human beings have several senses. They include sight, hearing, balance, touch, taste, and smell. We have special sense organs for each of these senses. What is the sense organ for sight? Eyes. For hearing? Ears.

Sensory neurons in each sense organ receive stimuli, or messages from the environment that cause a response in the body. For example, sensory neurons in the eyes send messages to the brain about light. Sensory neurons in the skin send messages to the brain about touch. Our sense organs recognize sensations, but they don't tell us *what* we are sensing. For example, when you breathe in chemicals given off by baking cookies, your nose does not tell you that you are smelling cookies. That's your brain's job. The sense organs send messages about sights, smells, and other stimuli to the brain (**Figure** 9.8). The brain then reads the messages and tells you what they mean. A certain area of the brain receives and interprets information from each sense organ. For example, information from the nose is received and interpreted by the temporal lobe of the cerebrum.

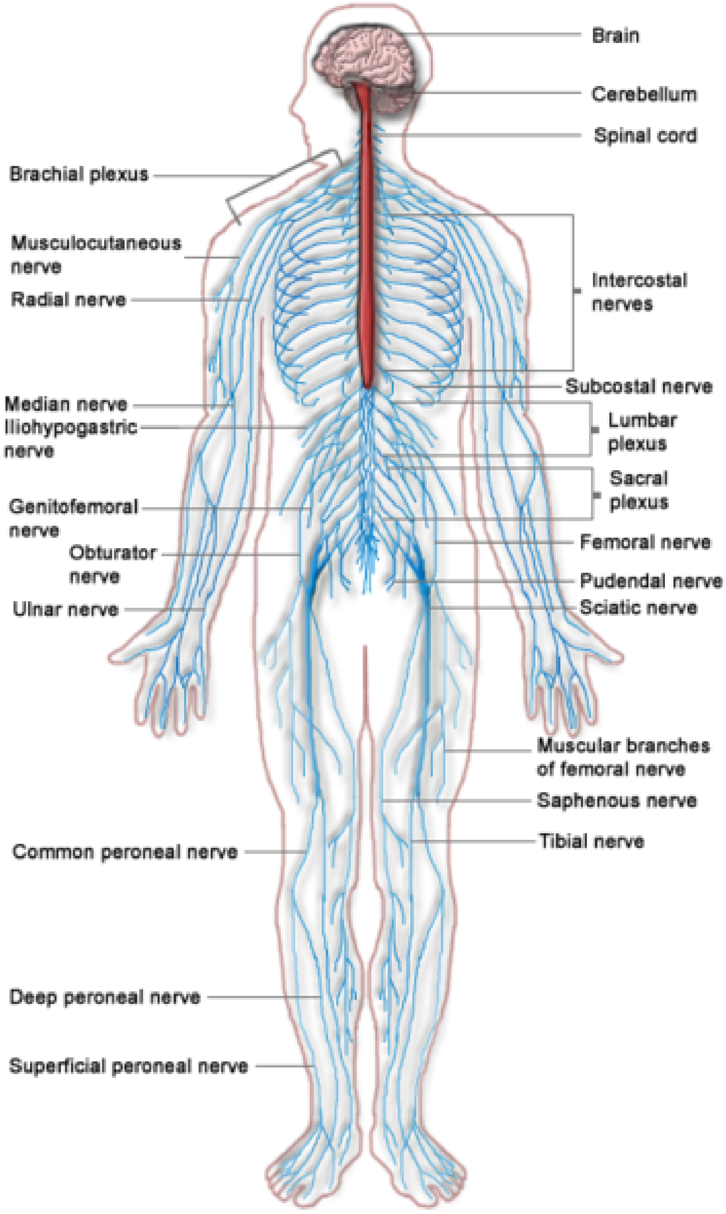


Figure 9.6: The blue lines in this drawing represent nerves of the peripheral nervous system. Every peripheral nerve is connected directly or indirectly to the spinal cord.

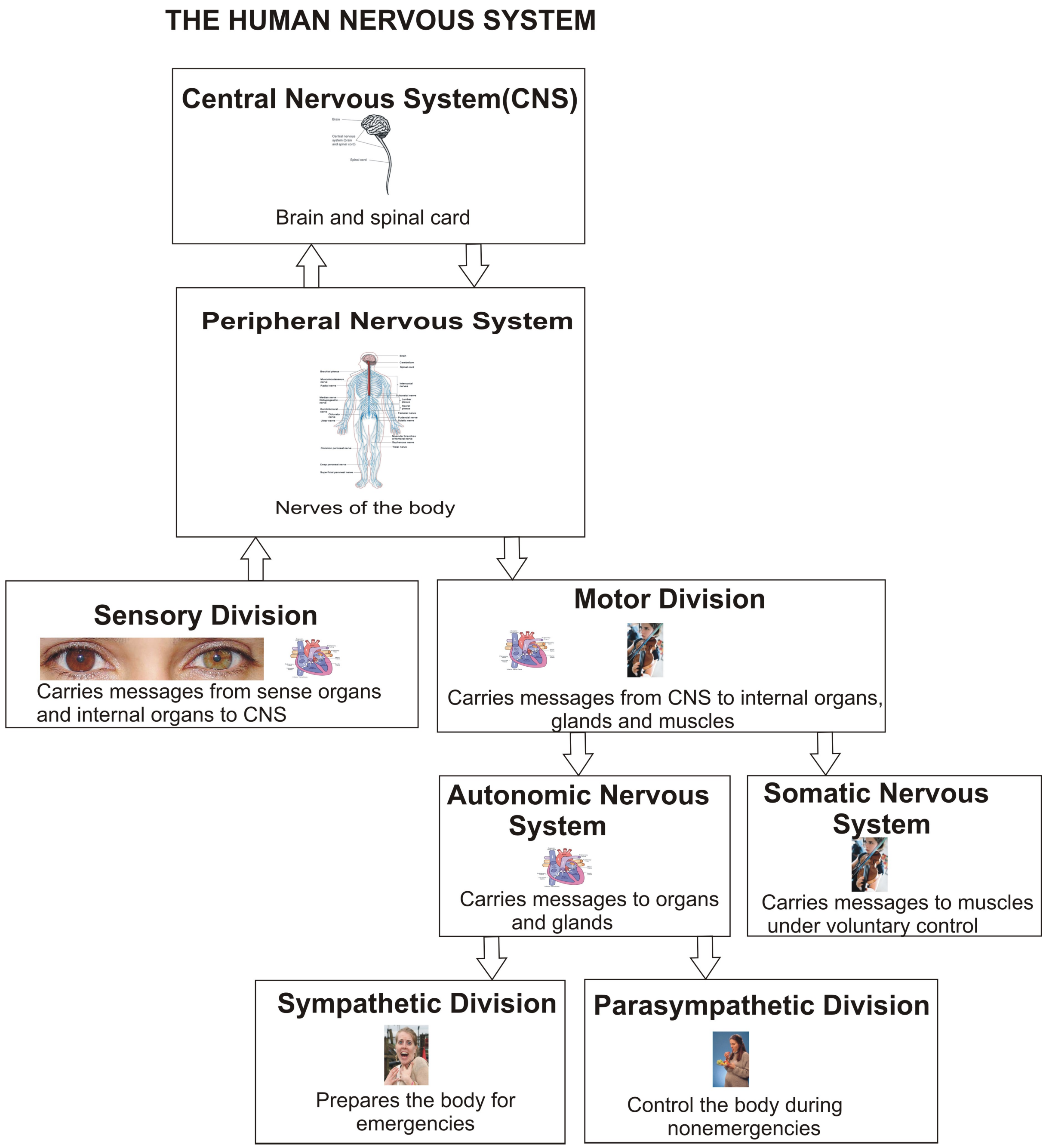

THE HUMAN NERVOUS SYSTEM
Central Nervous System(CNS)
Brain and spinal card
Peripheral Nervous System
Nerves of the body
Sensory Division
Carries messages from sense organs and internal organs to CNS
Motor Division
Carries messages from CNS to internal organs, glands and muscles
Autonomic Nervous System
Carries messages to organs and glands
Somatic Nervous System
Carries messages to muscles under voluntary control
Sympathetic Division
Prepares the body for emergencies
Parasympathetic Division
Control the body during nonemergencies

Figure 9.7: The central nervous system interprets messages from sense organs and internal organs and the motor division sends messages to internal organs, glands, and muscles.

Figure 9.8: Which lobes of the cerebrum interpret messages from each of the senses? Which senses would be stimulated by these raspberries? Look back at for clues.

The Motor Division

The **motor division** of the peripheral system carries messages from the central nervous system to internal organs and muscles. **Figure** 9.7 shows that the motor division is also divided into two parts, the somatic nervous system and the autonomic nervous system.

The **somatic nervous system** carries messages that control body movements. It is responsible for activities that are under your control, such as waving your hand or kicking a ball. The girl in **Figure** 9.9 is using her somatic nervous system to control the muscles needed to play the violin. Her brain sends messages to motor neurons that move her hands so she can play. Without the messages from her brain, she would not be able to move her hands and play the violin.

Figure 9.9: This girl's central nervous system is controlling the movements of her hands and arms as she plays the violin. Her brain is sending commands to her somatic nervous system, which controls the muscles of her hands and arms.

The **autonomic nervous system** carries nerve impulses to internal organs. It controls activities that are not under your control, such as sweating and digesting food. The autonomic nervous system has two parts:

1. The **sympathetic division** controls internal organs and glands during emergencies. It prepares the body for fight or flight (**Figure** 9.10). For example, it increases the heart rate and the flow of blood to the legs, so you can run away from danger.
2. The **parasympathetic division** controls internal organs and glands during the rest of the time. It controls processes like digestion, heartbeat, and breathing when there is not an emergency.

Remember Michelle on her scooter at the start of this lesson? Why was her heart pounding after she got

Figure 9.10: The woman pictured here is just pretending to be frightened, but assuming that she really was scared, think of which division of the autonomic nervous system would prepare her body for an emergency.

her balance back? The answer is her autonomic nervous system. The sympathetic division prepared her to deal with the emergency by increasing her heart rate. The fact that this happened in the blink of an eye shows how amazing the nervous system is.

Lesson Summary

- The nervous system controls all of the other systems of the body.
- Neurons are nerve cells that carry nerve impulses. The central nervous system is made up of the brain and spinal cord.
- The peripheral nervous system consists of all the rest of the nerves in the body.

Review Questions

Recall

1. List three functions of the nervous system.
2. Describe a neuron and identify its three main parts.
3. What two structures make up the central nervous system?
4. Name the lobes of the cerebrum and state one function of each lobe.
5. What are the two major divisions of the peripheral nervous system?

Apply Concepts

6. Explain how one neuron transmits a nerve impulse to another neuron.
7. Compare and contrast the three main parts of the brain.

8. Why is the spinal cord like a two-way highway?

Critical Thinking

9. A baby girl sees a toy and reaches out to grab it. Describe the path of messages through the baby's nervous system, from her eyes to her hand.

10. Assume you are so startled by a sudden loud noise that your heart starts pounding fast. Explain what controls your reaction to the loud sound.

Further Reading / Supplemental Links

- CK12 High School *Biology,* Chapter 35 http://biology.clc.uc.edu/Courses/bio105/nervous.htm.
- Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.
- Chris Hawkes. *The Human Body: Uncovering Science.* Firefly Books, 2006.
- F. Fay Evans-Martin. *The Nervous System.* Chelsea House Publications, 2004.
- H.P. Newquist. *The Great Brain Book: An Inside Look at the Inside of Your Head.* Scholastic Nonfiction, 2005.
- Treays, Rebecca. *Understanding Your Brain.* Usborne Books, 2004.
- http://www.pbs.org/wgbh/nova/magnetic/animals.html
- http://www.pelagic.org/overview/articles/sixsense.html
- http://en.wikipedia.org/wiki/Autonomic_nervous_system
- http://en.wikipedia.org/wiki/Brain_stem

Points to Consider

- The sensory division of the peripheral nervous system carries messages from sense organs to the central nervous system. What are some examples of sense organs?
- Do you know how sense organs work? For example, do you know how your eyes sense light?

9.2 Eyes and Vision

Lesson Objectives

- Describe how humans see and explain why vision is important.
- Explain how the eye works to produce images.
- Describe the nature of light.
- Explain how lenses correct vision problems.

Check Your Understanding

- What are some ways that people use their eyes?
- Which part of the nervous system carries messages from the eyes to the central nervous system?
- Which part of the brain interprets messages from the eyes?

Vocabulary

cornea iris lens
myopia pupil retina
visible light vision wavelength

The Nature of Human Vision

Think about all the ways that students use their sense of sight during a typical school day. As soon as they open their eyes in the morning, they may look at the clock to see what time it is. Then, they might look out the window to see what the weather is like. They probably look in a mirror to comb their hair. In school, they use their eyes to read the board, their textbooks, and the expressions on their friend's faces. After school, they may keep their eye on the ball while playing basketball (**Figure** 9.11). Then, they might read their homework assignment and text messages from their friends.

You may use your sight just as much as the students described above. In fact, you may depend on your sight so much that you have a hard time thinking of anything you do without it, except sleep. Why is sight so important?

Figure 9.11: All eyes are on the ball in this basketball game. Think about how we use the sense of sight in other games.

Sight, or **vision**, is the ability to see light. It depends on the eyes detecting light and forming images. It also depends on the brain making sense of the images, so we know what we are seeing. Human beings and other primates depend on vision more than many other animals. It's not surprising, then, that we have a better sense of vision than many other animals. Not only can we normally see both distant and close-up objects clearly, but we can also see in three dimensions and in color.

Seeing in Three Dimensions

Did you ever use 3-D glasses to watch a movie, like the boy in **Figure** 9.12? If you did, then you know that the glasses make people and objects in the movie appear to jump out of the screen. They make images on the flat movie screen seem more realistic because they give them depth. That's the difference between seeing things in two dimensions and three dimensions.

Figure 9.12: This boy is wearing 3-D glasses; when you look at objects and people in the real world, your eyes automatically see in three dimensions.

We are able to see in three dimensions because we have two eyes facing the same direction but a few inches apart. As a result, we see objects and people with both eyes at the same time, but from slightly different angles. Hold up a finger a few inches away from your face, and look at it first with one eye and then with the other. You'll notice that your finger appears to move.

Now hold up your finger at arm's length, and look at it with one eye and then the other. Your finger seems to move less than it did when it was closer. Although you aren't aware of it, your brain constantly uses such differences to determine the distance of objects.

Seeing in Color

For animals like us that see in color, it may be hard to imagine a world that appears to be mainly shades of gray. You can get an idea of how many other animals see the world by looking at a black-and-white picture of colorful objects.

For example, look at the apples on the tree **Figure ??**. In the top picture, they appear in color, the way you would normally see them. In the bottom picture they appear without color, in shades of gray (**Figure** 9.14).

Evolution and Primate Vision

Why do you think primates, including humans, evolved the ability to see in three dimensions and in color? To answer that question, you need to know a little about primate evolution. Millions of years ago, primate ancestors lived in trees. To move about in the trees, they needed to be able to judge how far away the next branch was. Otherwise, they might have a dangerous fall. Being able see in depth was important. It was an adaptation that would help tree-living primates survive.

Primate ancestors also mainly ate fruit. They needed to be able to spot colored fruits in the leafy background of the trees (**Figure** 9.15). They also had to be able to judge which fruits were ripe and which were

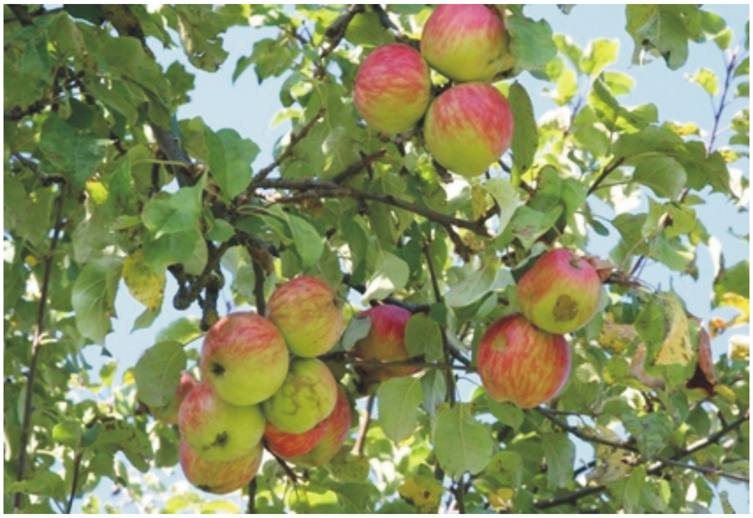


Figure 9.13: Humans with color vision see the apples on this tree; the bright red color of the apples stands out clearly from the green background of leaves.

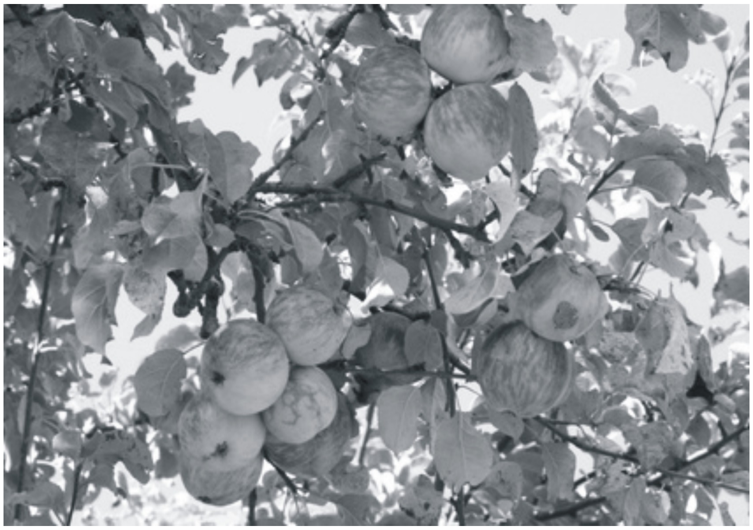


Figure 9.14: Dogs and cats would see the green and red colors as shades of gray; they are able to see blue, but red and green appear the same to them.

still green. Ripe fruits are usually red, orange, yellow, or purple. Being able to see in color was important for finding food. It was an adaptation that would help fruit-eating primates survive.

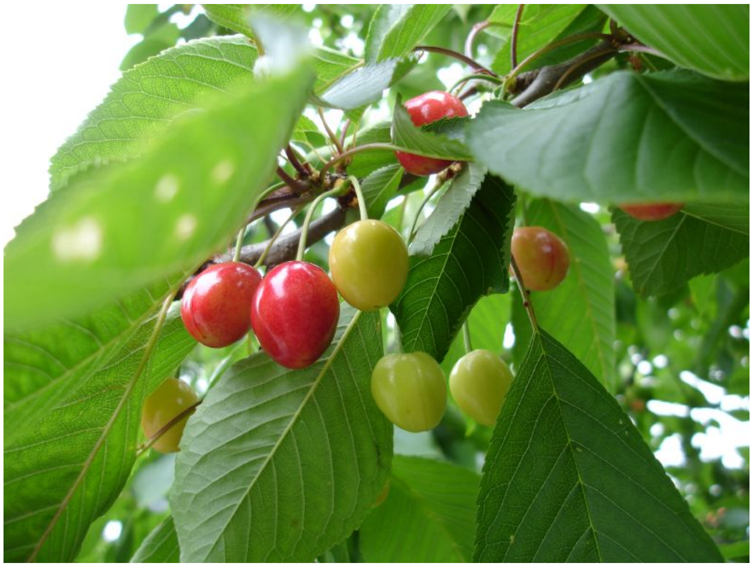


Figure 9.15: With color vision, you can tell which cherries in this picture are ripe, because cherries turn red as they ripen.

Knowing about primate evolution helps explain why we see the way we do. But it does not explain how we see as we do. What allows us to see in three dimensions and in color? To answer that question, you need to know how the eye works.

How the Eye Works

The job of the eye is to focus light. The parts of the eye, shown in **Figure** 9.16, help it to carry out its job. Follow the path of light through the eye as you read about it below.

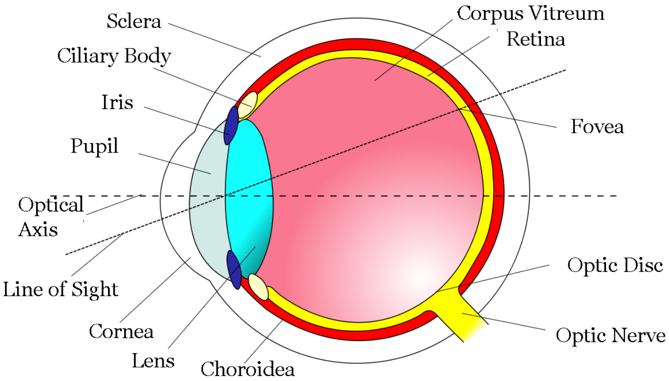


Figure 9.16: The human eye is a complex structure that senses light; the light passes through the cornea, pupil, and lens, and is focused on the retina.

Vision involves sensing and focusing light from people and objects. The steps involved are as follows:

1. First, light passes through the **cornea** of the eye. The cornea is a clear, protective covering on the outside of the eye.

2. Next, light passes through the pupil. The **pupil** is a black opening in the eye that lets light enter the eye. Surrounding the pupil is the **iris,** most commonly brown, blue, gray, or green.
3. After passing into the eye through the pupil, light passes through the lens. The **lens** of the eye is a clear, curved structure. Along with the cornea, the lens helps focus light at the back of the eye. This is shown in **Figure** 9.17.
4. The lens must bend light from nearby objects more than it bends light from far-away objects. The lens changes shape to bend the light by just the right amount to bring objects into focus.
5. The lens focuses light on the **retina**, which covers the back of the inside of the eye. The retina has light-sensing cells called rods and cones. Rods let us see in dim light. Cones let us detect light of different colors.
6. When light hits rods and cones, it causes chemical changes. The chemical changes start nerve impulses. The nerve impulses travel to the brain through the optic nerve.
7. The brain makes sense of the nerve impulses and tells you what you are seeing.

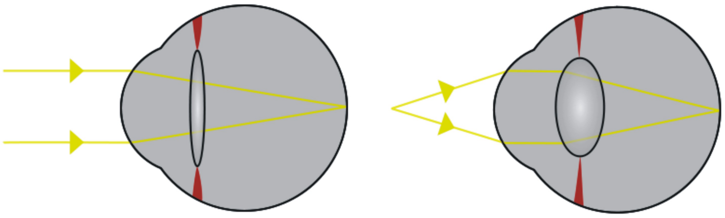


Figure 9.17: Light from objects at different distances is focused by the lens of the eye. Muscles in the eye control the shape of the lens so the light is focused on the back of the eye no matter how far the object is from the lens.

The Nature of Light

Now you know that eyes sense light. But do know what light is? You need to understand light to fully understand vision.

Visible light is a type of electromagnetic (EM) radiation. EM Radiation describes how waves move through space. Other types of EM Radiation include microwaves. But visible light is the only type of EM radiation that can be sensed by the human eye. To be visible to humans, EM radiation has to travel in waves of certain wavelengths. **Wavelength** is the distance from any point on one wave to the same point on the next wave. The different types of electromagnetic radiation are shown in **Figure** 9.18. Just a small part of the full range of EM radiation is visible to the human eye.

Colors of Light

Visible light from the sun does not have color. But if you bend visible light by passing it through a prism, it produces a "rainbow" of light of different colors (**Figure** 9.19). Why does this happen? Different colors of visible light have slightly different wavelengths. Light of different wavelengths bends by different degrees when it passes through a prism. This separates visible light into all of its colors.

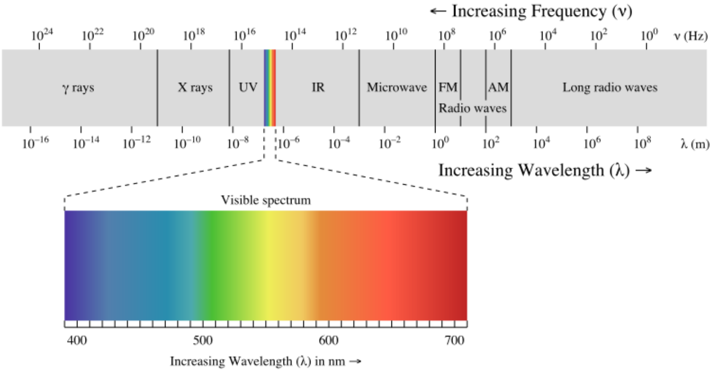


Figure 9.18: This diagram shows the wavelengths of electromagnetic radiation, from shortest (extreme left) to longest (extreme right); the human eye can sense only visible light, which falls in a narrow range of wavelengths, but the eyes of some animals can detect radiation of different wavelengths; bees can see ultraviolet radiation.

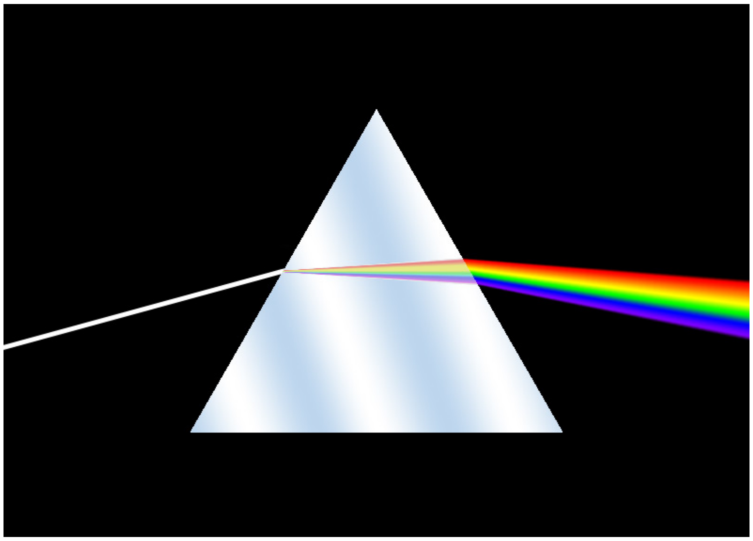


Figure 9.19: A prism bends white light to create a “rainbow” of red, orange, yellow, green, blue, indigo, and violet light.

Light and Vision

Except for objects that give off their own light, we don't see things just because light strikes them. We see things because light strikes them and then reflects, or bounces back, from their surface. What we see is the reflected light. Some things reflect all the light that strikes them. These things appear white. Some things do not reflect any light. Instead, they absorb all the light that strikes them. These things appear black. Other things, like the beads in **Figure** 9.20, reflect just one wavelength of light. Whatever wavelength they reflect is the color we see. For example, beads that reflect only red light look red to us.

Figure 9.20: These plastic beads reflect light of different wavelengths, so they appear to be different colors.

Lenses and Vision Correction

You probably know people that need eyeglasses or contact lenses to see clearly. Maybe you need them yourself. Lenses are used to correct vision problems. Two of the most common vision problems are myopia and hyperopia.

Myopia

Myopia is also called nearsightedness. It affects about one third of people. People with myopia can see nearby objects clearly, but distant objects appear blurry. How a person with myopia might see two boys that are a few meters away is shown in **Figure** 9.21.

In myopia, the eye is too long. In **Figure** 9.22, you can see how images are focused on the retina of someone with myopia. Myopia is corrected with a concave lens, which curves inward like the inside of a bowl. The lens changes the focus so images fall on the retina as they should.

Farsightedness

Farsightedness is also known as hyperopia. It affects about one fourth of people. People with hyperopia can see distant objects clearly, but nearby objects appear blurry. In hyperopia, the eye is too short. As shown in **Figure** 9.22, this results in images being focused in back of the retina. Hyperopia is corrected

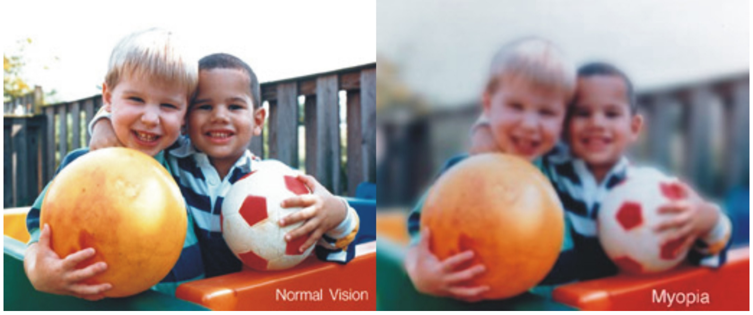


Figure 9.21: On the left, you can see how a person with normal vision sees two boys. The right image shows how a person with myopia sees the boys.

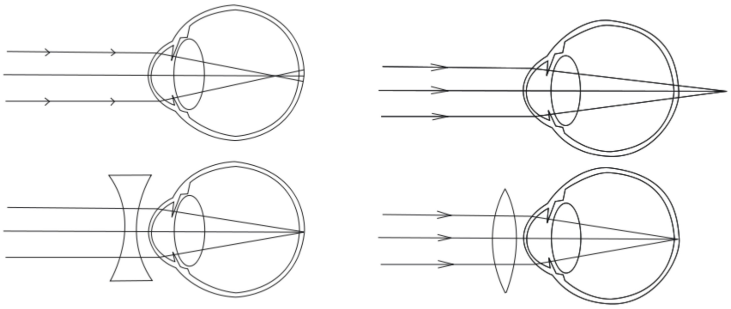


Figure 9.22: The eye of a person with myopia is longer than normal. As a result, images are focused in front of the retina (top left), A concave lens is used to correct myopia to help focus images on the retina (bottom left). Farsightedness occurs when objects are focused in back of the retina (top right). It is corrected with a convex lens (bottom right).

with a convex lens, which curves outward like the outside of a bowl. The lens changes the focus so images fall on the retina as they should.

In addition to lenses, many cases of myopia and hyperopia can be corrected with surgery. For example, a procedure called LASIK uses a laser to permanently change the shape of the cornea so light is correctly focused on the retina.

Lesson Summary

- Humans can normally see both distant and close-up objects clearly, and we also see in three dimensions and color.
- Light entering the eye is focused by the lens on the retina, which sends messages to the brain through the optic nerve.
- Visible light is electromagnetic radiation that can be detected by the human eye.
- Vision problems such as myopia and hyperopia can be corrected with lenses that help focus light on the retina.

Further Reading / Supplemental Links

- CK12 High School Biology, Chapter 35 `http://www.fda.gov/CDRH/LASIK`
- Body Atlas. *Nerves, Brain and Senses.* Ticktock Media Ltd., 2004.
- Donald B. Light. *The Senses.* Chelsea House Publications, 2004.
- Christopher Sloan. *The Human Story: Our Evolution from Prehistoric Ancestors to Today.* National Geographic Children's Books, 2004.
- `http://www.veterinaryvision.com/See.htm`
- `http://en.wikipedia.org/wiki`

Review Questions

Recall

1. What is vision?

2. Describe the lens of the eye and what it does.

3. What is hyperopia?

Apply Concepts

4. What happens when light is focused on the retina of the eye?

5. Black is sometimes defined as the absence of light. Why?

6. Assume you see a bright red apple. Why does the apple look red?

7. What causes myopia, and what type of lens corrects it?

Critical Thinking

8. Explain how humans can see in three dimensions.

9. Why were depth perception and color vision important for early primates?

Points to Consider

- The sense of sight is important to humans and other animals, but other senses may be equally important. What are some of our other senses?
- Why are these other senses important to us? For example, what are some ways we depend on our sense of hearing?

9.3 Other Senses

Lesson Objectives

- Explain how the ears hear and help maintain balance.
- Outline how we sense pressure, temperature, and pain.
- Describe how we identify different tastes and smells.
- Explain why hearing, balance, touch, taste, and smell are important.

Check Your Understanding

- What is the role of the nervous system?
- How do signals (”messages”) get from one area of the body to the brain?

Vocabulary

anvil cochlea ear
ear canal eardrum hammer
hearing oval window pinna
reflex arc semicircular canals stirrup
taste buds touch

Hearing and Balance

Imagine walking through the fruit market shown in **Figure** 9.23. What do you sense with your eyes? All of the brightly colored fruits. You would also hear the noisy bustle of the market. As you checked to see if a piece of fruit was firm, you would feel its smooth skin. If you tried a sample of the fruit, you would taste its juicy sweetness. Clearly, a market like this is a feast for all of the senses. In this lesson, you will read how your nervous system senses the sound, feel, taste, and smell of a market like this — and of everything else around you.

What do listening to music and riding a bike have in common? It might surprise you to learn that both activities depend on your ears. The **ears** are sense organs that detect sound. They also sense the position of the body and help maintain balance.

Figure 9.23: This outdoor fruit market stimulates all the senses — sight, sound, smell, taste, and touch.

Hearing

Hearing is the ability to sense sound. Sound travels through the air in waves, much like the waves you see in the water in **Figure** 9.24 and the light waves described in the previous lesson. Sound waves in air cause vibrations inside the ears. The ears sense the vibrations.

Figure 9.24: Sound waves travel through the air in all directions away from a sound like waves traveling through water away from where a pebble was dropped.

What the human ear looks like is shown in **Figure** 9.25. As you read about it below, trace the path of sound waves through the ear. You can also see an animation of the ear sensing sound at `http://www.sumanasinc.com/webcontent/animations/content/soundtransduction.html`.

Assume a car horn blows in the distance. Sound waves spread through the air from the horn. Some of the sound waves reach your ear. The steps below show what happens next. They explain how your ears sense the sound.

1. The sound waves enter the **pinna**, or outer ear. This is the part of the ear you can see.
2. The sound waves travel to the **ear canal**. This is a tube-shaped opening in the ear.
3. At the end of the ear canal, the sound waves hit the **eardrum**. This is a thin membrane that vibrates like the head of a drum when sound waves hit it.
4. The vibrations pass from the eardrum to the **hammer**. This is the first of three tiny bones that pass vibrations through the ear.
5. The hammer passes the vibrations to the **anvil**, the second tiny bone that passes vibrations through the ear.
6. The anvil passes the vibrations to the **stirrup**, the third tiny bone that passes vibrations.
7. From the stirrup, the vibrations pass to the **oval window**. This is another membrane like the eardrum.
8. The oval window passes the vibrations to the **cochlea**. The cochlea is filled with liquid that moves when the vibrations pass through, like the waves in water when you drop a pebble into a pond. Tiny hair cells line the cochlea and bend when the liquid moves. When the hair cells bend, they release

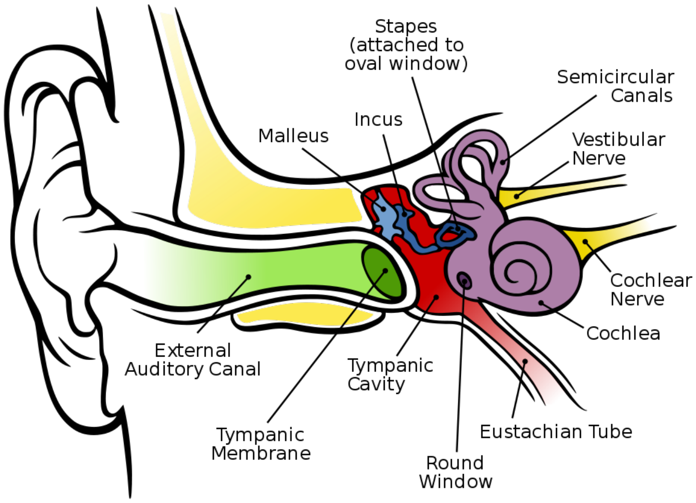


Figure 9.25: Read the names of the parts of the ear in the text, then find each of the parts in the diagram.

neurotransmitters.

9. The neurotransmitters trigger nerve impulses that travel to the brain through the auditory nerve. The brain reads the sound and "tells" you what you are hearing.

No doubt you've been warned that listening to loud music or other loud sounds can damage your hearing. It's true. In fact, repeated exposure to loud sounds is the most common cause of hearing loss. The reason? Very loud sounds can kill the tiny hair cells lining the cochlea. The hair cells do not generally grow back once they are destroyed, so this type of hearing loss is permanent. You can protect your hearing by avoiding loud sounds or wearing earplugs or other ear protectors.

Balance

Did you ever try to stand on one foot with your eyes closed? Try it and see what happens, but be careful! It's harder to keep your balance when you can't see. Your eyes obviously play a role in balance. But your ears play an even bigger role. The gymnast in **Figure** 9.26 may not realize it, but her ears — along with her cerebellum — are mostly responsible for her ability to perform on the balance beam.

The parts of the ears involved in balance are the **semicircular canals**. In **Figure** 9.25, the semicircular canals are the parts numbered 10. The canals contain liquid, and are like the bottle of water in **Figure** 9.27. When the bottle tips, the water surface moves up and down the sides of the bottle. When the body tips, the liquid in the semicircular canals moves up and down the sides of the canals.

Tiny hair cells line the semicircular canals. Movement of the liquid inside the canals causes the hair cells to send nerve impulses. The nerve impulses travel to the cerebellum in the brain. In response, the cerebellum sends commands to muscles to contract or relax so the body stays balanced.

Touch

When you look at the prickly cactus in **Figure** 9.28, does the word "ouch" come to mind? Touching the cactus would be painful. **Touch** is the sense of pain, pressure, or temperature. Touch depends on sensory neurons in the skin. The skin on the palms of the hands, soles of the feet, and face has the most

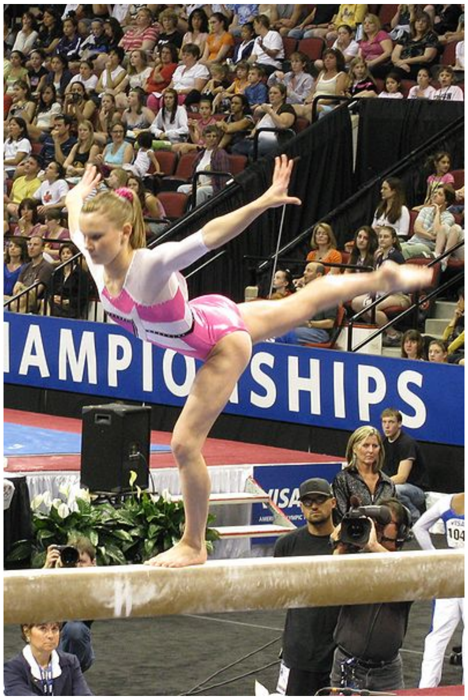


Figure 9.26: This gymnast is using the semicircular canals in her ears, along with the cerebellum in her brain, to help keep her balance on the balance beam.

Figure 9.27: This bottle of water models the semicircular canals in your ears. When you tip the bottle, the water moves up or down the sides of the bottle; when you tip your head, the liquid inside the semicircular canals moves up and down the sides of the canals. Tiny hair cells lining the canals sense the movement of liquid and send messages to the brain.

sensory neurons and is especially sensitive to touch. The tongue and lips are very sensitive to touch as well. Neurons that sense pain are also found inside the body in muscles, joints, and organs. If you have a stomach ache or pain from a sprained ankle, it's because of these sensory neurons found inside of your body.

Figure 9.28: The spines on this cactus are like needles, they help keep away animals that might want to eat the cactus.

The following example shows how messages about touch travel from sensory neurons to the brain, as well as how the brain responds to the messages. Suppose you wanted to test the temperature of the water in a lake before jumping in. You might stick one bare foot in the water. Neurons in the skin on your foot would sense the temperature of the water and send a message about it to your central nervous system. The frontal lobe of the cerebrum would process the information. It might decide that the water is really cold and send a message to your muscles to pull your foot out of the water.

In some cases, messages about pain or temperature don't travel all the way to and from the brain. Instead, they travel only as far as the spinal cord, and the spinal cord responds to the messages by giving orders to the muscles. When messages avoid the brain in this way, it forms a **reflex arc**, like the one shown in **Figure** 9.29. A detailed view of the spinal cord is shown in **Figure** 9.30.

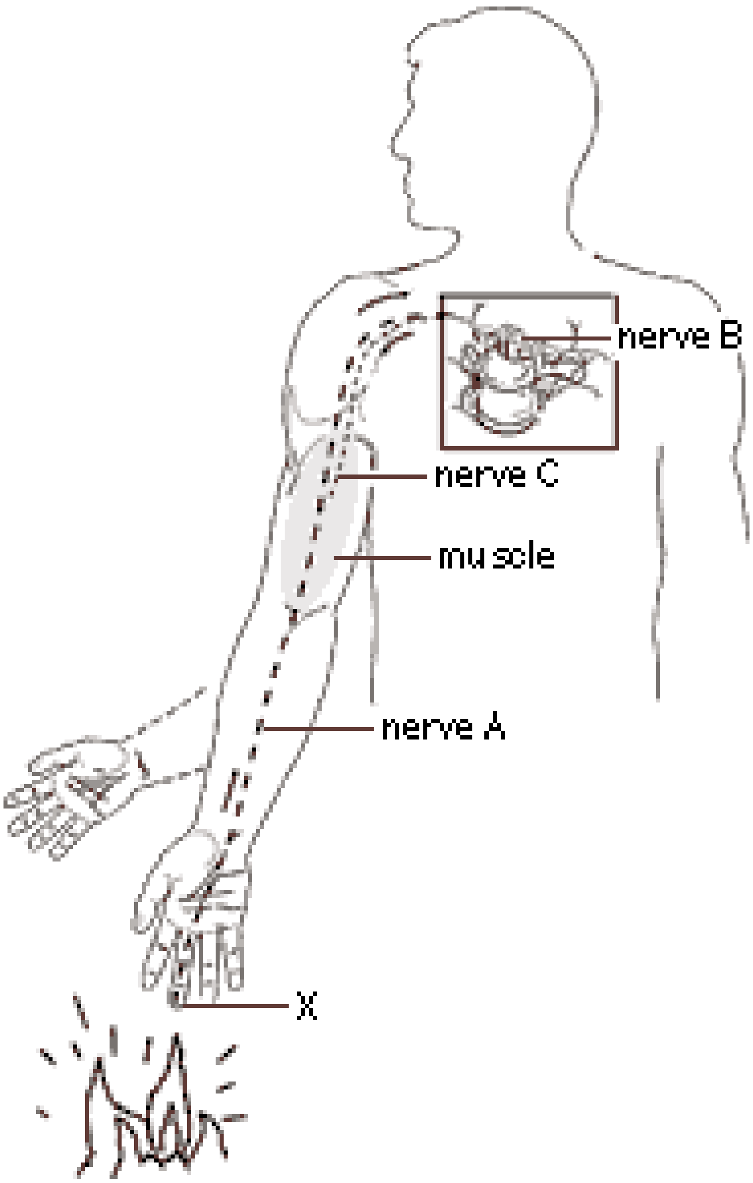


Figure 9.29: Reflex Arc: When you touch something hot, you may immediately jerk your hand away - without even thinking about it.

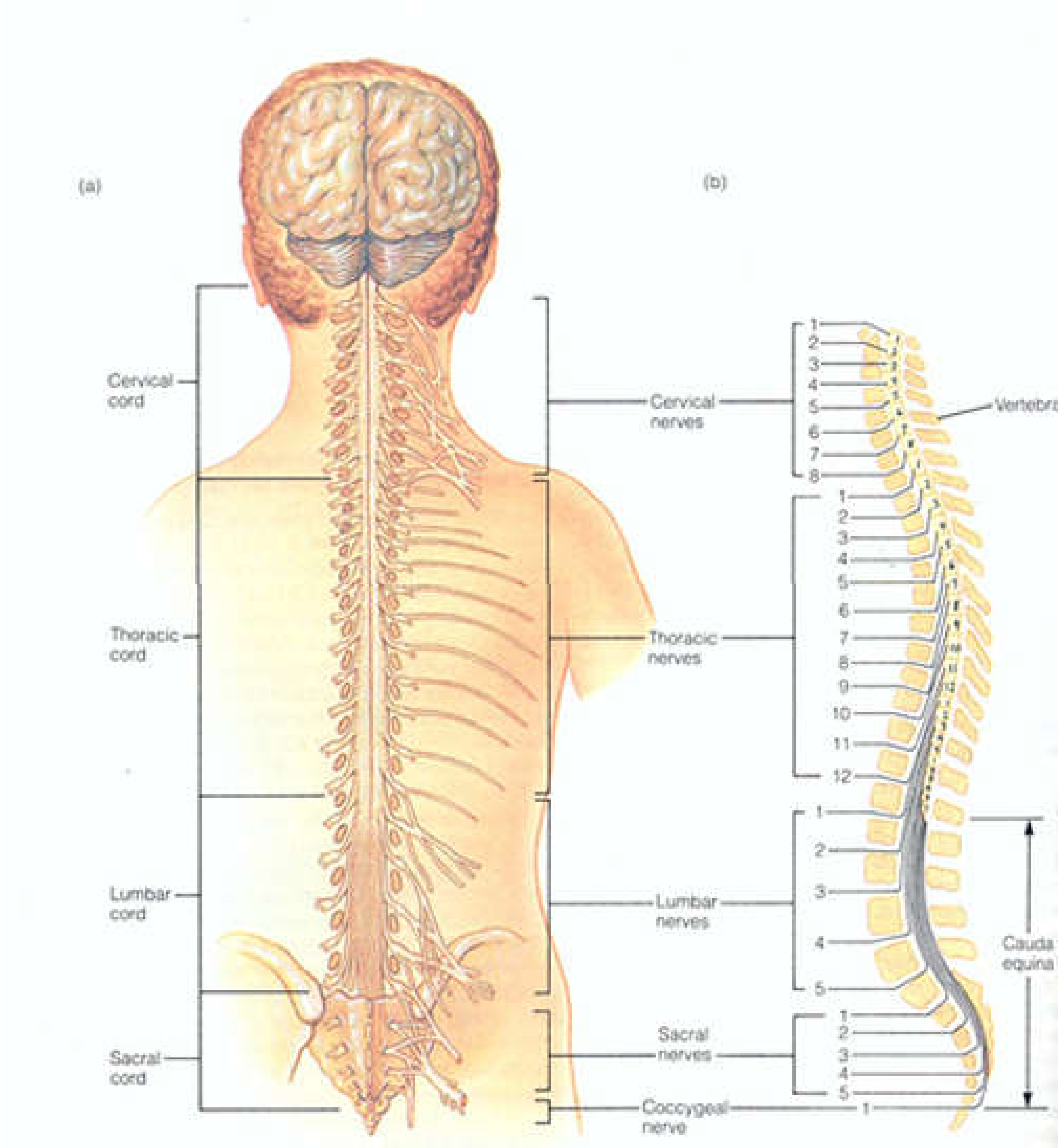


Figure 9.30: Reflex Arc: The nerve impulse from your hand travels to the spinal cord and the spinal cord sends a message to your muscles to pull back your hand. A detailed view of the spinal cord is shown here.

Taste and Smell

Your sense of taste is controlled by sensory neurons on your tongue that sense the chemicals in food. The neurons are grouped in bundles within **taste buds** (**Figure** 9.31). There are five different types of taste neurons on the tongue. Each type detects a different taste. The tastes are

1. Sweet.
2. Salty.
3. Sour.
4. Bitter.
5. Umami, which is a meaty taste.

When taste neurons sense chemicals, they send messages to the brain about them. The brain then decides what tastes you are sensing.

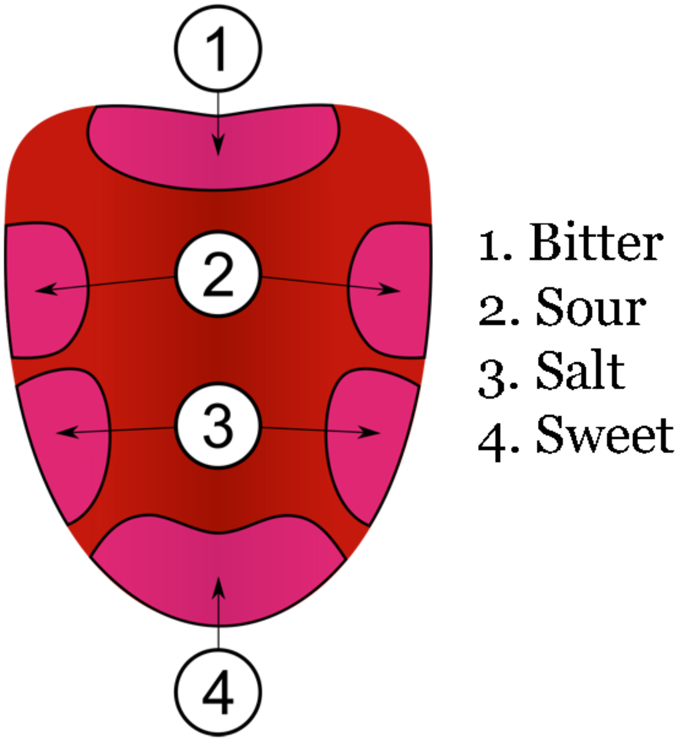


Figure 9.31: Tiny bumps that cover the tongue contain taste buds, bundles of sensory neurons that allow you to detect different types of tastes, such as sweet and salty tastes.

Your sense of smell also involves sensory neurons that sense chemicals. The neurons are found in the nose, and they detect chemicals in the air. Unlike taste neurons, which can detect only five different tastes, the sensory neurons in the nose can detect thousands of different odors. Have you ever noticed that you lose your sense of taste when your nose is stuffed up? That's because your sense of smell greatly affects your ability to taste food. As you eat, molecules of food chemicals enter your nose. You experience the taste and smell at the same time. Being able to smell as well as taste food greatly increases the number of different tastes you are able to sense. For example, you can use your sense of taste alone to learn that a food is sweet, but you have to use your sense of smell as well to learn that the food tastes like strawberry cheesecake.

Lesson Summary

- The ears detect sound waves and help maintain balance. The skin senses pain, pressure, and temperature.
- Sensory cells on the tongue and in the nose detect tastes and smells.
- The senses of hearing, balance, touch, taste, and smell give us information about our life and help keep us safe.

Further Reading / Supplemental Links

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Review Questions

Recall

1. What are the two main functions of the ears?
2. Which structure in the ear changes sound waves in the air into vibrations?
3. What happens after the oval window in the ear passes vibrations to the cochlea?
4. Which parts of the ear sense changes in the body's position?
5. What are the five tastes sensed by neurons on the tongue?

Apply Concepts

6. Why does death of hair cells in the cochlea cause hearing loss?
7. How and why do reflex arcs occur?
8. Why is your sense of taste affected when you have a stuffy nose?
9. How could the ability to feel pain help prevent serious injury? Give an example.

Critical Thinking

10. Explain the statement, "You listen with your ears, but you hear with your brain."

Points to Consider

- Our senses, along with the rest of our nervous system, help us stay safe. At least they do if our nervous system is healthy. But what if the nervous system itself becomes ill or injured? What do you think would happen then? How do you think nervous system problems affect the rest of the body?

9.4 Health of the Nervous System

Lesson Objectives

- Describe diseases of the nervous system.
- Explain how the nervous system can be injured.
- Identify the dangers of alcohol and other drugs.
- List ways to keep the nervous system healthy.

Check Your Understanding

- What is the role of the nervous system?
- What are some of the main parts of the nervous system?

Vocabulary

concussion drug drug abuse
drug addiction drug overdose hallucinogenic drug
paralysis physical dependence stimulant drug
tolerance tumor withdrawal

Nervous System Diseases

The nervous system controls sensing, feeling, and thinking. It also controls movement and just about every other body function. That's why problems with the nervous system can affect the entire body. Nervous system problems include diseases and injuries. Most nervous system diseases cannot be prevented. But you can take steps to decrease your risk of nervous system injuries.

Diseases of the nervous system include brain and spinal cord infections. Other problems of the nervous system range from very serious diseases, such as tumors, to less serious problems, such as tension headaches. Some diseases are present at birth. Others begin during childhood or adulthood.

Central Nervous System Infections

When you think of infections, you probably think of an ear infection or strep throat. You probably don't think of a brain or spinal cord infection. But bacteria and viruses can infect these organs as well as other parts of the body. At the same time, infections of the brain and spinal cord are not very common. But when they happen, they can be very serious. That's why it's important to know their symptoms.

Encephalitis

Encephalitis is a brain infection (**Figure** 9.32). If you have encephalitis, you are likely to have a fever and headache or feel drowsy and confused. The disease is most often caused by viruses. The immune system tries to fight off a brain infection, just as it tries to fight off other infections. But sometimes this can do more harm than good. The immune system's response may cause swelling in the brain. With no room to expand, the brain pushes against the skull. This may injure the brain and even cause death. Medicines can help fight some viral infections of the brain, but not all infections.

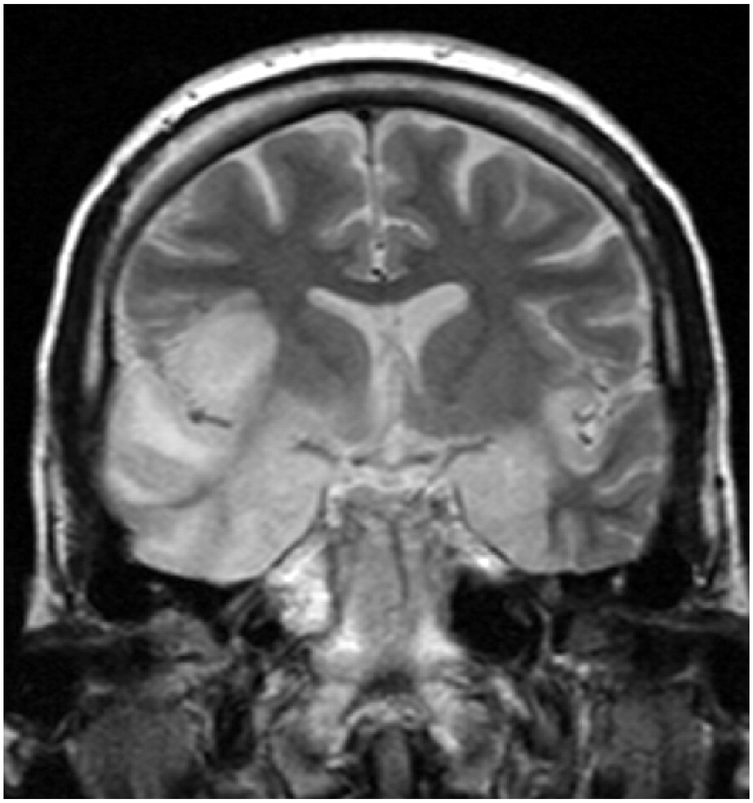


Figure 9.32: This scan shows a person with encephalitis.

Meningitis

Meningitis is an infection of the membranes that cover the brain and spinal cord. If you have meningitis, you are likely to have a fever and headache. Another telltale symptom is a stiff neck. Meningitis can be caused by viruses or bacteria. Viral meningitis often clears up on its own after a few days. Bacterial meningitis is much more serious (**Figure** 9.33). It may cause brain damage and death. People with bacterial meningitis need emergency medical treatment. They are usually given antibiotics to kill the bacteria.

A vaccine to prevent meningitis recently became available. It can be given to children as young as 2 years old. Many doctors recommend that children receive the vaccine no later than age 12 or 13, or before they begin high school.

Reye's Syndrome

A condition called Reye's syndrome can occur in young people that take aspirin when they have a viral infection. The syndrome causes swelling of the brain and may be fatal. Fortunately, Reye's syndrome is very rare. The best way to prevent it is by not taking aspirin when you have a viral infection. Products like cold medicines often contain aspirin. So, read labels carefully when taking any medicines (**Figure** 9.34).

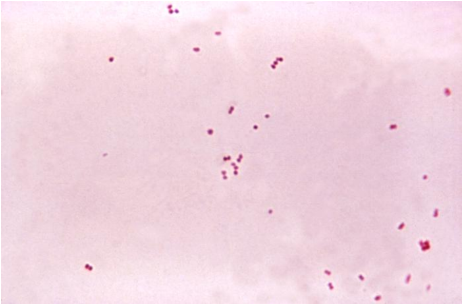
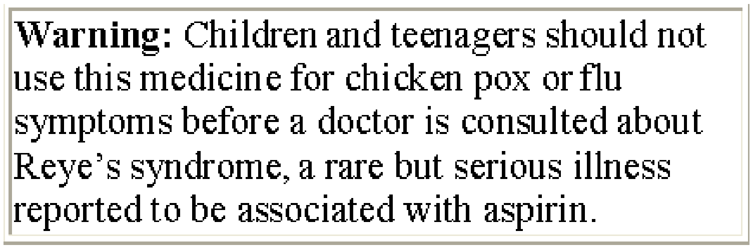


Figure 9.33: These bacteria — shown at more than 1,000 times their actual size - are the cause of bacterial meningitis. Despite their tiny size, they can cause very serious illness.



Warning: Children and teenagers should not use this medicine for chicken pox or flu symptoms before a doctor is consulted about Reye's syndrome, a rare but serious illness reported to be associated with aspirin.

Figure 9.34: Since 1988, the U.S. Food and Drug Administration has required that all aspirin and aspirin-containing products carry this warning label.

Other Nervous System Diseases

Like other parts of the body, the nervous system may develop tumors. A **tumor** is a mass of cells that grow out of control. A tumor in the brain may press on normal brain tissues. This can cause headaches, difficulty speaking, or other problems, depending on where the tumor is located. Pressure from a tumor can even cause permanent brain damage. In many cases, brain tumors can be removed with surgery. In other cases, tumors can't be removed without damaging the brain even more. In those cases, other types of treatments may be needed.

Cerebral palsy is a disease caused by injury to the developing brain. The injury occurs before, during, or shortly after birth. Cerebral palsy is more common in babies that have a low weight at birth. But the cause of the brain injury is not often known. The disease usually affects the parts of the brain that control body movements. Symptoms range from weak muscles in mild cases to trouble walking and talking in more severe cases. There is no known cure for cerebral palsy.

Epilepsy is a disease that causes seizures. A seizure is a period of lost consciousness that may include violent muscle contractions. It is caused by abnormal electrical activity in the brain. The cause of epilepsy may be an infection, brain injury, or tumor. The seizures of epilepsy can often be controlled with medicine. There is no known cure for the disease, but children with epilepsy may outgrow it by adulthood.

A headache is a very common nervous system problem. Headaches may be a symptom of serious diseases, but they are more commonly due to muscle tension. A tension headache occurs when muscles in the shoulders, neck, and head become too tense. This often happens when people are "stressed out." Just trying to relax may help relieve this type of headache (**Figure** 9.35). Mild pain relievers such as ibuprofen may also help.

A migraine is a more severe type of headache. It occurs when blood vessels in the head dilate, or expand. This may be triggered by certain foods, bright lights, weather changes, or other factors. People with

Figure 9.35: Sometimes relaxation is the best "medicine" for a tension headache, and to help muscles get rid of pain.

migraines may also have nausea or other symptoms. Fortunately, migraines can often be relieved with prescription drugs.

There are many other nervous system diseases. They include multiple sclerosis, Huntington's disease, Parkinson's disease, and Alzheimer's disease. However, these diseases rarely, if ever, occur in young people. Their causes and symptoms are listed in **Table** 9.2. The diseases have no known cure, but medicines may help control their symptoms.

Table 9.2: **Other Diseases of the Nervous System**

Disease	Cause	Symptoms
Multiple Sclerosis	The immune system attacks and damages the central nervous system so neurons cannot function normally.	Muscle weakness, difficulty moving, problems with coordination, difficulty keeping the body balanced
Huntington's Disease	An inherited gene codes for an abnormal protein that causes the death of neurons.	Uncontrolled jerky movements, loss of muscle control, problems with memory and learning
Parkinson's Disease	An abnormally low level of a neurotransmitter affects the part of the brain that controls movement.	Uncontrolled shaking, slowed movements, problems with speaking
Alzheimer's Disease	Abnormal changes in the brain cause the gradual loss of most normal brain functions.	Memory loss, confusion, mood swings, gradual loss of control over mental and physical abilities

Injuries to the Central Nervous System

Injuries to the central nervous system may damage tissues of the brain or spinal cord. If an injury is mild, a person may have a full recovery. If an injury is severe, it may cause permanent disability or even death. Brain and spinal cord injuries most commonly occur because of car crashes or sports accidents. The best way to deal with such injuries is to try to prevent them.

Brain Injuries

The mildest and most common type of brain injury is a **concussion**. This is a bruise on the surface of the brain. It may cause temporary problems such as headache, drowsiness, and confusion. Most concussions

Spinal Cord Injuries

Spinal cord injuries make it difficult for messages to travel between the brain and body. They may cause a person to lose the ability to feel or move parts of the body. This is called **paralysis**. Whether paralysis occurs — and what parts of the body are affected if it does — depends on the location and seriousness of the injury. In addition to car crashes and sports injuries, diving accidents are a common cause of spinal cord injuries.

Some people recover from spinal cord injuries. But many people are paralyzed for life. Thanks to the work of Christopher Reeve (**Figure** 9.36), more research is being done on spinal cord injuries now than ever before. For example, scientists are trying to discover ways to regrow damaged spinal cord neurons.

Figure 9.36: Former star Christopher Reeve was paralyzed from the neck down in a fall from a horse. The injury crushed his spinal cord so his brain could no longer communicate with his body.

Dangers of Alcohol and Other Drugs

A **drug** is any chemical substance that affects the body or brain. Some drugs are medicines (**Figure** 9.37). Although these drugs are helpful when used properly, they can be misused like any other drugs. Drugs that aren't medicines include both legal and illegal drugs. Examples of legal drugs are alcohol and caffeine. Although these drugs can be used legally by adults, they can still do harm. Examples of illegal drugs include marijuana and cocaine.

Types of Psychoactive Drugs

Drugs like alcohol, marijuana, and cocaine affect the brain. Drugs that affect the brain are called psychoactive drugs. They influence how a person feels, thinks, or acts. You can watch animations of psychoactive drugs and the brain at `http://www.pbs.org/wnet/closetohome/science/html/animations.html.` .

If you think you have never used a psychoactive drug, think again. Do you drink soft drinks, such as colas? Most of them contain caffeine, which is a psychoactive drug. Caffeine is also found in coffee and chocolate (**Figure** 9.38).

Caffeine is an example of a class of psychoactive drugs called stimulant drugs. Other classes of psychoactive drugs are depressant drugs and hallucinogenic drugs. Drugs are classified based on how they affect the nervous system.

Figure 9.37: Drugs that are prescribed by a doctor can be misused just like illegal drugs.

Figure 9.38: All three of these popular products contain the stimulant drug caffeine.

- A **stimulant drug** is a psychoactive drug that speeds up the nervous system. This type of drug may make people feel more alert. Stimulants also increase heart rate and blood pressure. High doses of stimulant drugs can be dangerous. They can even cause death. Other stimulant drugs include nicotine (in tobacco) and cocaine.
- A depressant drug is a psychoactive drug that slows down the nervous system. This type of drug may make people feel calm and drowsy. It also decreases heart rate and the rate of breathing. High doses of depressant drugs can be dangerous. They may slow down the nervous system so much that heartbeat and breathing stop. Examples of depressant drugs include alcohol and morphine.
- A **hallucinogenic drug** is a psychoactive drug that can cause strange sensations, perceptions, and thoughts. Examples of hallucinogenic drugs include marijuana and LSD.

Drug Abuse

Psychoactive drugs, both legal and illegal, are often abused. **Drug abuse** is the use of a drug without the advice of a doctor or for reasons other than the intended use of the drug. Drug abuse may lead to **physical dependence** on the drug. This occurs when drug abusers need a drug to feel well physically. If they stop using the drug, they may experience symptoms like vomiting, diarrhea, or depression. This is called **withdrawal**. Drug abuse may also lead to psychological dependence. This happens when drug abusers need a drug to feel well emotionally and mentally.

For some drug abusers, a drug takes over their life. Their thoughts and activities revolve around getting and using the drug. No matter what the consequences, they keep using the drug. Even if they want to stop using the drug, they can't. When drug abuse reaches this state, it's called **drug addiction**. Alcohol, nicotine, and cocaine are all highly addictive drugs.

People that are addicted to a drug may need to take more of the drug to feel the same effects as when they first started using the drug. This is called **tolerance**. People that develop tolerance are at risk of a **drug overdose**. A drug overdose occurs when someone takes so much of a drug that it causes serious illness or death.

Keeping the Nervous System Healthy

There are many choices you can make to keep your nervous system healthy. One obvious choice is to avoid using alcohol or other drugs. Not only will you avoid the injury that drugs themselves can cause. You will also be less likely to get involved in other risky behaviors that could harm your nervous system. Another way to keep the nervous system healthy is to eat a variety of healthy foods. The minerals calcium and potassium and vitamins B_1 and B_{12} are important for a healthy nervous system. Some foods that are good sources for these minerals and vitamins are shown **Figure** 9.39.

Daily physical activity is also important for nervous system health. Regular exercise makes your heart more efficient at pumping blood to your brain. As a result, your brain gets more oxygen, which it needs to function normally. The saying "use it or lose it" applies to your brain as well as your body. This means that mental activity, not just physical activity, is important for nervous system health. Doing crossword puzzles, reading, and playing a musical instrument are just a few ways you can keep your brain active.

You can also choose to practice safe behaviors to protect your nervous system from injury. To keep your nervous system safe, choose to:

- Wear safety goggles or sunglasses to protect your eyes from injury.
- Wear hearing protectors such as ear plugs to protect your ears from loud sounds.
- Wear a safety helmet for activities like bike riding and skating (**Figure** 9.40).

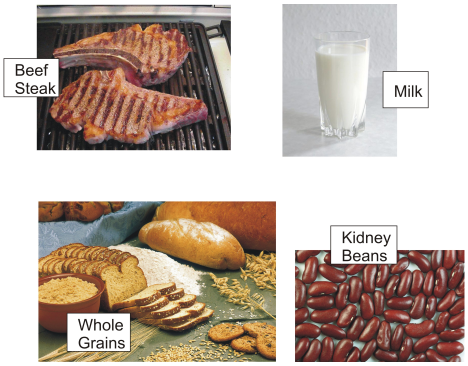


Figure 9.39: These foods are sources of nutrients needed for a healthy nervous system.

- Wear a safety belt every time you ride in a motor vehicle.
- Avoid unnecessary risks, such as performing dangerous stunts on your bike.
- Never dive into water that is not approved for diving. If the water is too shallow, you could seriously injure your brain or spinal cord. A few minutes of fun could turn into a lifetime in a wheelchair.

Figure 9.40: Bicycle helmets help protect from head injuries. Making healthy choices like this can help prevent nervous system injuries that could cause lifelong disability.

Lesson Summary

- The nervous system can be affected by infections, tumors, and other diseases.
- Brain or spinal cord injuries may cause permanent disability or even death.
- The use of psychoactive drugs can lead to drug abuse or addiction.
- You can make choices that will help keep your nervous system healthy and safe.

Review Questions

Recall

1. What is encephalitis?
2. List symptoms of a concussion.
3. Define ”psychoactive drug” and name two examples.

Apply Concepts

4. List three choices you can make to keep your nervous system healthy.
5. What causes muscle weakness in cerebral palsy?
6. Compare and contrast tension headaches and migraine headaches.
7. Explain what causes paralysis.
8. Which type of psychoactive drug is caffeine? How does caffeine affect the nervous system?

Critical Thinking

9. Explain why young people should not take aspirin when they have the flu, which is caused by viruses.
10. How is drug tolerance related to drug overdose?

Further Reading / Supplemental Links

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- http://en.wikipedia.org/wiki

Points to Consider

Next we look more at diseases.

- Give examples of pathogens.
- How do you think pathogens can cause disease?

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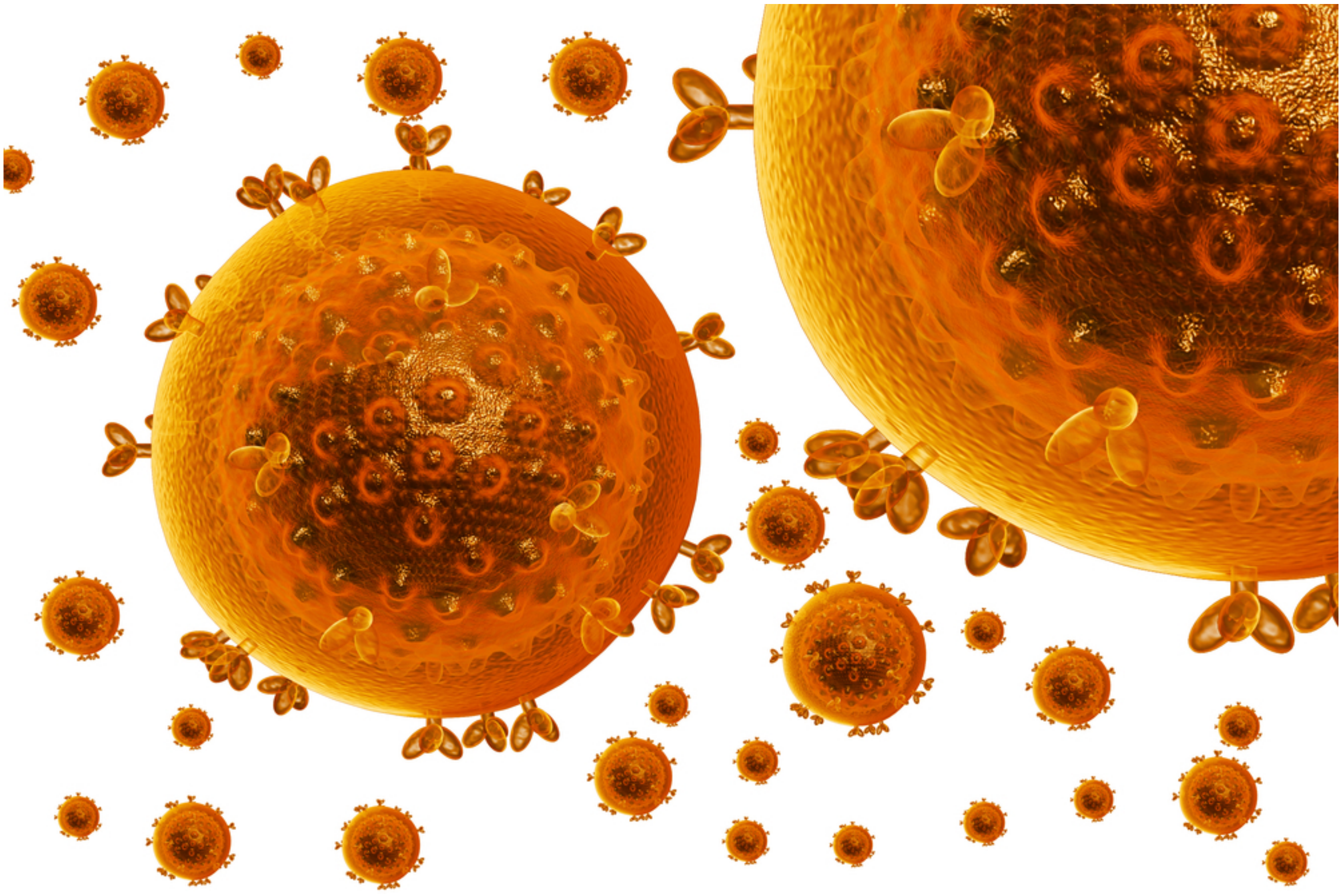
Chapter 10

MS Diseases and the Body's Defenses



What does the above image look like to you? A ball with sticks coming out of it? It is actually a human immunodeficiency virus (HIV). HIV is a deadly virus that is difficult for most humans to remove from their bodies.

You have an immune system that is supposed to stop viruses from infecting your body. So how do HIV and other diseases outsmart the body's immune system? What can we do to prevent HIV and other diseases from infecting our bodies? Why can't medicines cure HIV, but they can cure other illnesses?

Just because human immune systems cannot get rid of HIV, they still help people clear viruses and bacteria every moment of every day. How does the immune system remove dangerous diseases from our bodies? How can we improve our immune system's response to disease?

Your immune system is one of the most complex and interesting systems in your body. Consider the above questions as you read about the amazing ways that immune systems respond to diseases and also how they are limited by dangerous diseases, like HIV.

10.1 Infectious Diseases

Lesson Objectives

- List common causes of infectious diseases.
- Explain how the virus known as HIV causes AIDS.
- State how infectious diseases can be prevented.

Check Your Understanding

- What are bacteria?
- What is blood made out of?

Vocabulary

AIDS HIV infectious disease

Causes of Infectious Diseases

Has this ever happened to you? A student sitting next to you in class has a cold. The other student is coughing and sneezing, but you feel fine. Two days later, you come down with a cold, too. Diseases like colds are contagious. Contagious diseases are also called infectious diseases. An **infectious disease** is a disease that spreads from person to person.

Infectious diseases are caused by pathogens. A pathogen is a living thing or virus that causes disease. Pathogens are commonly called "germs." They can travel from one person to another.

Types of Pathogens

Living things that cause human diseases include bacteria, fungi, and protozoa. Most infectious diseases caused by these organisms can be cured with medicines. For example, medicines called antibiotics can cure most diseases caused by bacteria. Bacteria are one-celled organisms without a nucleus. Although most bacteria are harmless, some cause diseases.

Worldwide, the most common disease caused by bacteria is tuberculosis (TB). TB is a serious disease of the lungs. Another common disease caused by bacteria is strep throat. You may have had strep throat yourself. Bacteria that cause strep throat are shown in **Figure** 10.1. Some types of pneumonia and many cases of illnesses from food are also caused by bacteria.

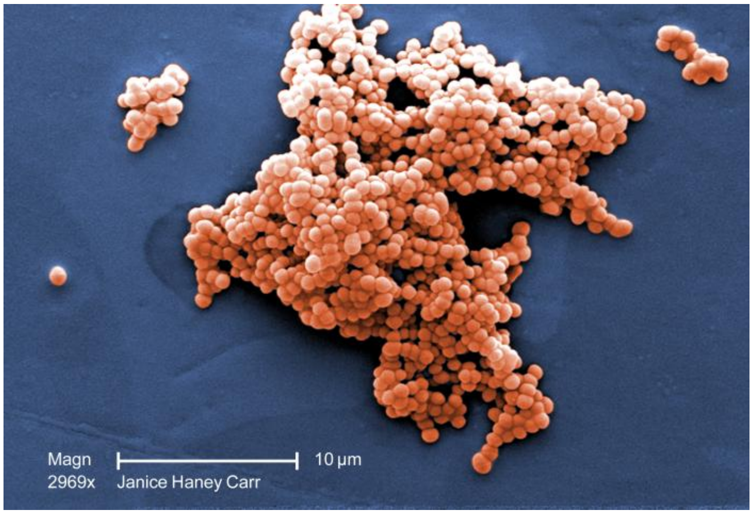


Figure 10.1: The structures that look like strings of beads are bacteria. They belong to the genus . Bacteria of this genus cause diseases such as strep throat and pneumonia. They are shown here 900 times bigger than their actual size.

Fungi are simple organisms that consist of one or more cells. They include mushrooms and yeasts. Human diseases caused by fungi include ringworm and athlete's foot. Both are skin diseases that are not usually serious. What a ringworm infection looks like is shown in **Figure** 10.2. A more serious fungus disease is histoplasmosis. It is a lung infection.

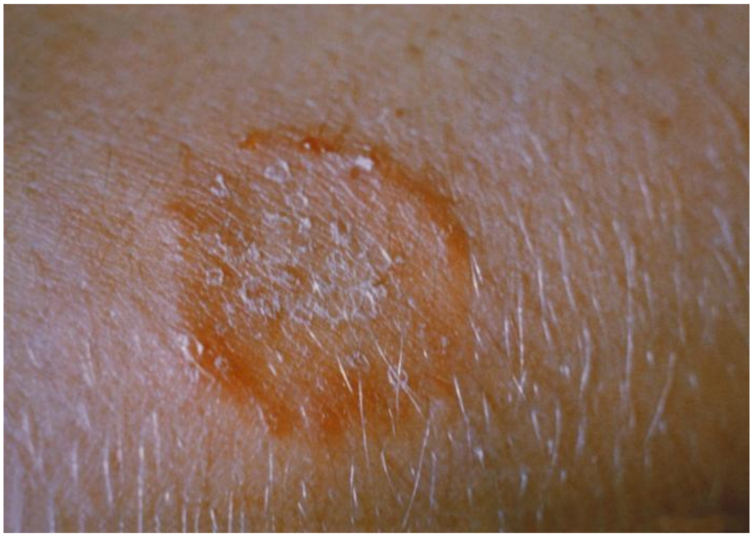


Figure 10.2: Ringworm isn't a worm at all. It's a disease caused by a fungus. The fungus causes a ring-shaped rash on the skin, like the one shown here.

Protozoa are one-celled eukaryotes. They cause diseases such as malaria. Malaria is a serious disease that is common in warm climates. The protozoa infect people when they are bit by a mosquito. More than a million people die of malaria each year. Other protozoa cause diarrhea. An example is *Giardia lamblia*, which is shown in **Figure** 10.3.

Viruses are nonliving collections of protein and DNA that must reproduce inside of living cells. Viruses cause many common diseases. For example, viruses cause colds and the flu. Cold sores are caused by

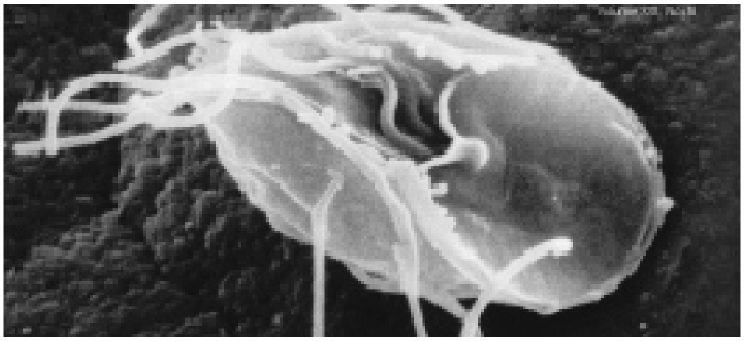


Figure 10.3: This picture shows a one-celled organism called . It is a protozoan that causes diarrhea.

the virus *Herpes simplex*. This virus is shown in **Figure** 10.4. Antibiotics do not affect viruses, because antibiotics only kill bacteria. But medicines called antiviral drugs can treat many diseases caused by viruses.

Figure 10.4: The virus, which is shown here, causes cold sores on the lips. Viruses are extremely small particles. This one is greatly magnified.

How Pathogens Spread

Different pathogens spread in different ways. Some pathogens spread through food. They cause food borne illnesses. These illnesses were discussed in the *Food and Digestive System* chapter. Some pathogens spread through water. *Giardia lamblia* is one example.

Water can be boiled to kill *Giardia* and most other pathogens. Several pathogens spread through sexual contact. HIV is one example. It is a virus you will read about below. Other pathogens that spread through sexual contact are discussed in the *Reproductive Systems and Life Stages* chapter.

Many pathogens that cause respiratory diseases spread by droplets in the air. Droplets are released when a person sneezes or coughs. Thousands of tiny droplets are released when a person sneezes, as shown in **Figure** 10.5. Each droplet can contain thousands of pathogens. Viruses that cause colds and the flu can spread in this way. You may get sick if you breathe in the pathogens.

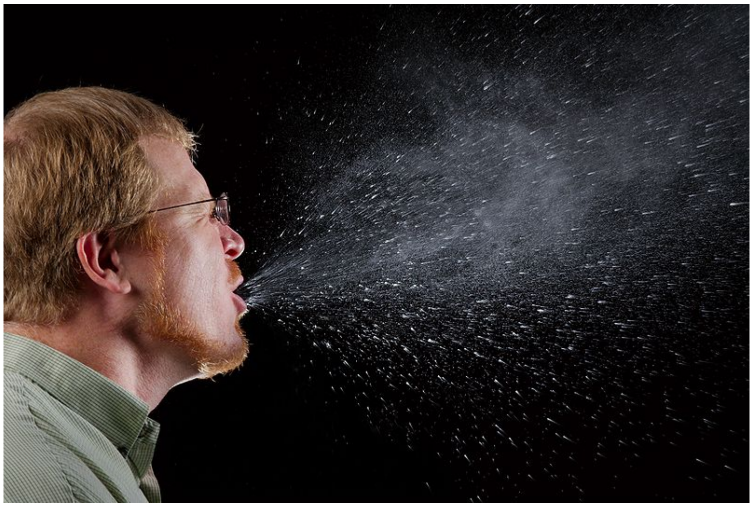


Figure 10.5: As this picture shows, thousands of tiny droplets are released into the air when a person sneezes. Each droplet may carry thousands of pathogens. You can't normally see the droplets from a sneeze because they are so small. However, you can breathe them in, along with any pathogens they carry. This is how many diseases of the respiratory system are spread.

Pathogens on Surfaces

Other pathogens spread when they get on objects or surfaces. A fungus may spread in this way. For example, you can pick up the fungus that causes athlete's foot by wearing shoes an infected person has worn. You can also pick up this fungus from the floor of a public shower. After acne, athlete's foot is the most common skin disease in the United States. Therefore, the chance of coming in contact with the fungus in one of these ways is fairly high.

Bacteria that cause the skin disease impetigo can spread when people share towels or clothes. The bacteria can also spread through direct skin contact in sports like wrestling.

Pathogens and Vectors

Still other pathogens are spread by vectors. A vector is an organism that carries pathogens from one person or animal to another. Most vectors are insects, such as ticks and mosquitoes. When an insect bites an infected person or animal, it picks up the pathogen. Then the pathogen travels to the next person or animal it bites. Ticks carry the bacteria that cause Lyme disease. Mosquitoes, like the one in **Figure** 10.6, carry West Nile virus. Both pathogens cause fever, headache, and tiredness. If the diseases are not treated, more serious symptoms may develop.

The first case of West Nile virus in North America occurred in 1999. Within just a few years, the virus had spread throughout most of the United States. Birds as well as humans can be infected with the virus. Birds often fly long distances. This is one reason why West Nile virus spread so quickly.

Figure 10.6: Some diseases are spread by insects. The type of mosquito shown here can spread West Nile virus. The virus doesn't make the mosquito sick. The mosquito just carries the virus from one person or animal to another.

HIV Infection and AIDS

HIV, or human immunodeficiency virus, causes AIDS. **AIDS** stands for "acquired immune deficiency syndrome." It is a condition that causes death and does not have a known cure. AIDS usually develops 10 to 15 years after a person is first infected with HIV. The development of AIDS can be delayed with proper medicines.

How HIV Spreads

HIV spreads through contact between an infected person's body fluids and another person's bloodstream or mucus membranes, which are found in the mouth, nose, and genital areas. Body fluids that may contain HIV are blood, semen, vaginal fluid, and breast milk. The virus can spread through sexual contact or shared drug needles. It can also spread from an infected mother to her baby during childbirth or breastfeeding.

Some people think they can become infected with HIV by donating blood or receiving donated blood. This is not true. The needles used to draw blood for donations are always new. Therefore, they cannot spread the virus. Donated blood is also tested to make sure it is does not contain HIV.

HIV and the Immune System

How does an HIV infection develop into AIDS? HIV destroys white blood cells called helper T cells. The cells are produced by the immune system. This is the body system that fights infections and other diseases.

You will read more about the immune system later in this chapter. HIV invades helper T cells and uses them to reproduce. This is shown in **Figure** 10.7. Then, the virus kills the helper T cells. As the number of viruses in the blood rises, the number of helper T cells falls. Without helper T cells, the immune system is unable to protect the body. The infected person cannot fight infections and other diseases because they do not have T cells. This is why people do not die from HIV. Instead, they die from another illness, like the common cold, that they cannot fight because they do not have helper T cells.

Medications can slow down the increase of viruses in the blood. But the medications cannot remove the viruses from the body. At present, there is no cure for HIV infection.

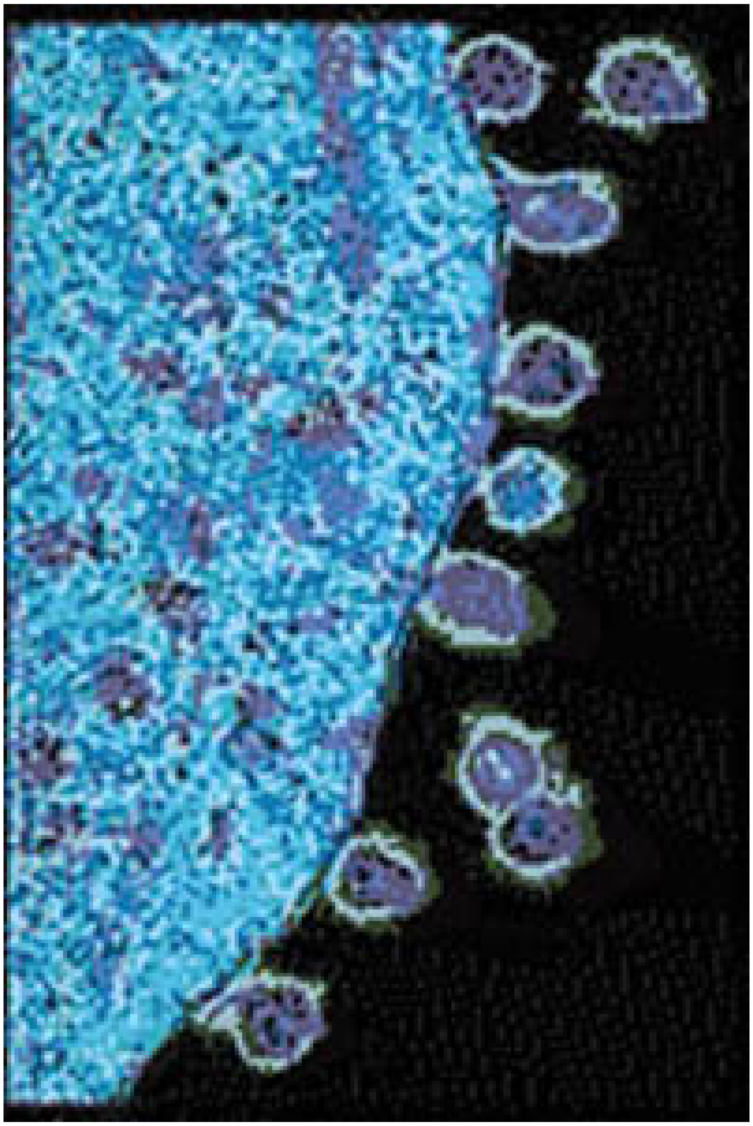


Figure 10.7: In this picture, the large structure on the left is a helper T cell. It is infected with HIV. The many small circles on the right are new HIV viruses being shed by the T cell.

AIDS

AIDS is not really a single disease. It is a set of symptoms and other diseases. It results from years of damage to the immune system by HIV. AIDS occurs when helper T cells fall to a very low level and the person develops infections or cancers that people with a healthy immune system can easily resist. These diseases are usually the cause of death of people with AIDS.

The first known cases of AIDS occurred in 1981. Since then, AIDS has led to the deaths of more than 25 million people worldwide. Many of them were children. The greatest number of deaths occurred in Africa. It is also where medications to control HIV are least available. There are currently more people infected with HIV in Africa than any other part of the world.

Preventing Infectious Diseases

What can you do to avoid infectious diseases? Eating right and getting plenty of sleep are a good start. These habits will help keep your immune system healthy. With a healthy immune system, you will be able to fight off many pathogens.

You can also take steps to avoid pathogens in the first place. The best way to avoid pathogens is to wash your hands often. You should wash your hands after using the bathroom or handling raw meat or fish. You should also wash your hands before eating or preparing food. In addition, you should wash your hands after being around sick people. The correct way to wash your hands is demonstrated in **Figure** 10.8. If soap and water aren't available, use a hand sanitizer. A hand sanitizer that contains at least 60 percent alcohol will kill most germs on your hands.

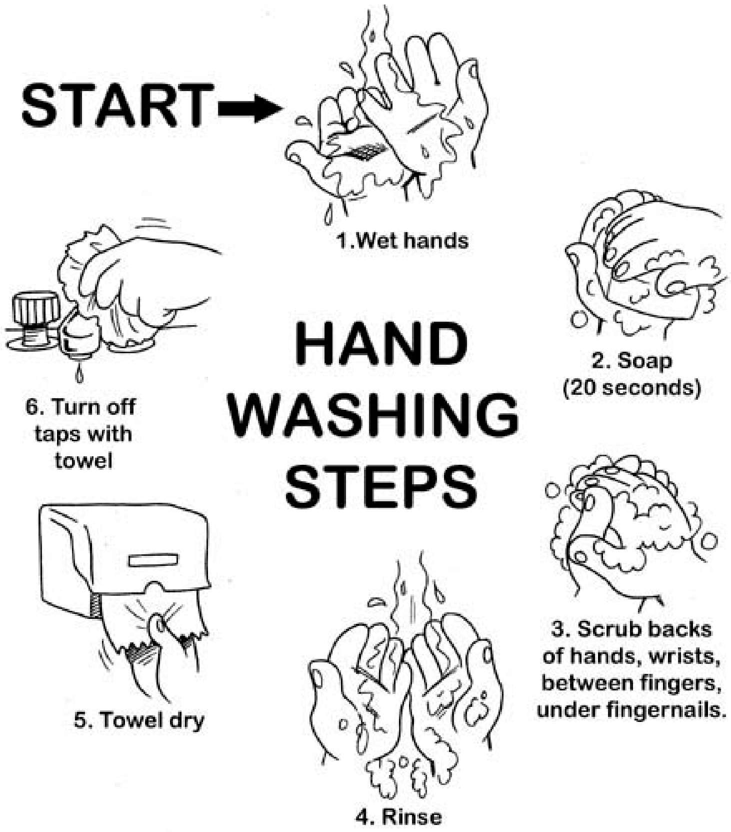


Figure 10.8: This picture shows the proper way to wash your hands. Frequent hand washing helps prevent the spread of pathogens.

The best way to prevent diseases spread by vectors is to avoid contact with the vectors. For example, you can wear long sleeves and long pants to avoid tick and mosquito bites. Using insect repellent can also reduce your risk of insect bites. Many infectious diseases can be prevented with vaccinations. You will read more about vaccinations later in this chapter. Vaccinations can help prevent measles, mumps, chicken pox, and several other diseases.

If you do develop an infectious disease, try to avoid infecting others. Stay home from school until you are well. Also, take steps to keep your germs to yourself. Cover your mouth and nose with a tissue when you sneeze or cough, and wash your hands often to avoid spreading pathogens to other people.

Lesson Summary

- Infectious diseases are caused by living things or viruses that can travel from one person to another.
- HIV causes AIDS by destroying disease-fighting cells produced by the immune system.
- A healthy lifestyle and frequent hand washing can help reduce your risk of infectious diseases.

Review Questions

Recall

1. Name two examples of infectious diseases.
2. What is a pathogen?
3. List three ways that pathogens can spread.
4. What is HIV?
5. What is the single most important way to avoid pathogens?

Apply Concepts

6. Why do antibiotics not cure the common cold?
7. Explain why covering your mouth when you cough helps prevent the spread of germs.
8. What role do vectors play in the spread of infectious diseases?
9. How does an HIV infection develop into AIDS?

Critical Thinking

10. Explain to a friend why using insect repellent reduces your risk of developing Lyme disease.
11. Explain why HIV does not kill people, but causes other illnesses to kill people infected with HIV.

Further Reading / Supplemental Links

- Jenna Bush. *Ana's Story: A Journey of Hope.* Harper Collins, 2007.
- Scientific American. *Germ Wars: Battling Killer Bacteria and Microbes.* Rosen Publishing Group, 2008.
- `http://www.cdc.gov/ncidod/dvbid/westnile/index.htm`
- `http://www.mayoclinic.com/health/germs/ID00002`
- `http://www.mayoclinic.com/health/infectious-disease/ID00004`
- [http://www.merck.com/mmhe/sec17/ch188/ch188a.html `http://www.merck.com/mmhe/sec17/ch188/ch188a.html`
- `http://www.niaid.nih.gov/healthscience/healthtopics/microbes/PDF/microbesbook.pdf`
- `http://www.nlm.nih.gov/medlineplus/infectiousdiseases.html`
- `http://www.who.int/mediacentre/factsheets/fs094/en/index.html`
- `http://www.nlm.nih.gov/medlineplus/infectiousdiseases.html`
- `http://www.who.int/mediacentre/factsheets/fs094/en/index.html`
- `http://en.wikipedia.org/wiki/West_nile_virus`

Points to Consider

- What do you think causes allergies?
- Do you know of other diseases that are not caused by pathogens?
- Do you think these diseases are contagious?

10.2 Noninfectious Diseases

Lesson Objectives

- List causes of noninfectious diseases.
- Describe causes and treatments of cancer.
- Explain why diabetes occurs.
- Describe autoimmune diseases and allergies.
- State how noninfectious diseases can be prevented.

Check Your Understanding

- What is an infectious disease?
- What are the stages of the cell cycle?

Vocabulary

allergy autoimmune disease diabetes
noninfectious disease type 1 diabetes type 2 diabetes

Causes of Noninfectious Diseases

Not all diseases spread from person to person. A disease that does not spread from person to person is called a **noninfectious disease**. An examples is cancer. Certain cancers may or may not be caused by pathogens.

Most noninfectious diseases have more than one cause. The causes may include genes and an unhealthy lifestyle. Having a specific gene may increase the chances that people will have certain diseases. But other factors, like lifestyle, may determine if the diseases actually develop. For example, what people eat or whether they smoke may also play a role in whether or not a person gets cancer.

Several noninfectious diseases are discussed in other chapters. For example, heart disease is discussed in *Cardiovascular System* chapter. In this lesson, the focus is on cancer, diabetes, and diseases of the immune system.

Cancer

Cancer is a disease that causes cells to divide out of control. Normally, the body has systems that prevent cells from dividing out of control, but in the case of cancer, these systems fail.

What Causes Cancer?

Cancer is usually caused by mutations. From the *Cell Division, Reproduction, and DNA* chapter, you know that mutations are random errors in genes. Mutations that lead to cancer usually happen to genes that control the cell cycle. Because of the mutations, abnormal cells divide uncontrollably. This often leads to the development of a tumor. A tumor is a mass of abnormal tissue. As a tumor grows, it may harm normal tissues around it.

Anything that can cause cancer is called a carcinogen. Carcinogens may be pathogens, chemicals, or radiation. **Figure** 10.9, **Figure** 10.10, and **Figure** 10.11 give examples of carcinogens.

Pathogens

Pathogens that cause cancer include the human papilloma virus (HPV) and the hepatitis B virus. HPV is spread through sexual contact. It can cause cancer of the reproductive system in females (**Figure** 10.9). The hepatitis B virus is spread through sexual contact or contact with blood containing the virus. It can cause cancer of the liver.

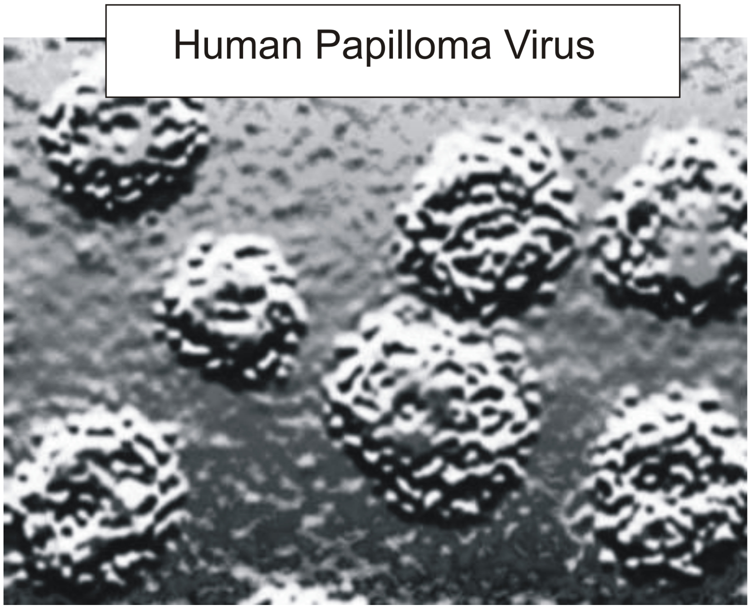


Figure 10.9: The mutations that cause cancer may occur when people are exposed to pathogens, such as the human papilloma virus (HPV), which is shown here.

Chemicals

Many different chemical substances cause cancer. Dozens of chemicals in tobacco smoke, including nicotine, have been shown to cause cancer. In fact, tobacco smoke is one of the main sources of chemical carcinogens. Smoking tobacco increases the risk of cancer of the lung, mouth, throat, and bladder. Using smokeless tobacco can also cause cancer.

Figure 10.10: The mutations that cause cancer may occur when people are exposed to chemical carcinogens, such as those in cigarettes.

Radiation

Forms of radiation that cause cancer include ultraviolet (UV) radiation and radon. UV radiation is part of sunlight. It is the leading cause of skin cancer. Radon is a natural radioactive gas that seeps into buildings from the ground. It can cause lung cancer (**Figure** 10.11).

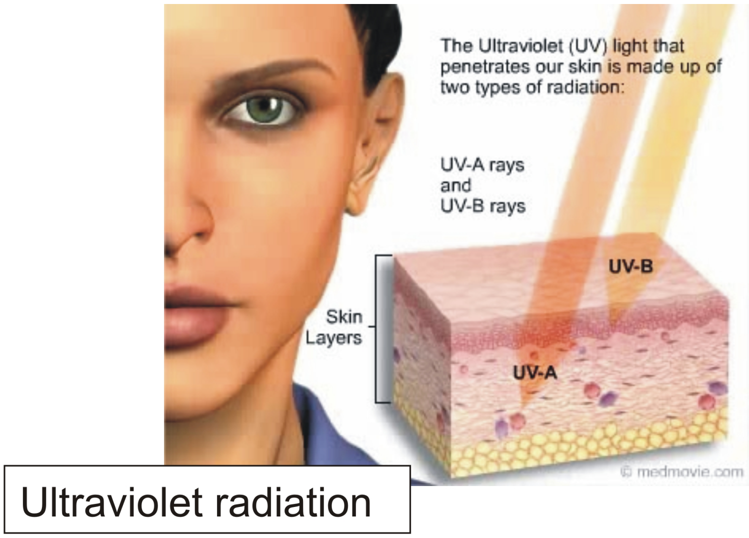

The Ultraviolet (UV) light that penetrates our skin is made up of two types of radiation:
UV-A rays and UV-B rays
Skin Layers
UV-B
UV-A
© medmovie.com
Ultraviolet radiation

Figure 10.11: The mutations that cause cancer may occur when people are exposed to radiation, including the radiation from sunlight.

Sometimes cancer cells break away from a tumor. If they enter the bloodstream, they are carried throughout the body. Then, the cells may start growing in other tissues. This is usually how cancer spreads from one part of the body to another. Once this happens, cancer is very hard to stop or control.

Common Types of Cancer

Cancer is usually found in adults, especially in adults over age 50. The most common type of cancer in adult males is cancer of the prostate gland. The prostate gland is part of the male reproductive system. Prostate cancer makes up about one third of all cancers in men. The most common type of cancer in adult females is breast cancer. It makes up about one third of all cancers in women. In both men and women, lung cancer is the second most common type of cancer. Most cases of lung cancer happen in people who smoke.

Cancer can also be found in children. But childhood cancer is rare. Leukemia is the main type of cancer in children. It makes up about one third of all childhood cancers. It happens when the body makes abnormal white blood cells.

Treating Cancer

If leukemia is treated early, it usually can be cured. In fact, many cancers can be cured if treated early. Treatment of cancer often involves removing a tumor with surgery. This may be followed by other types of treatments. These treatments may include drugs and radiation, which kill cancer cells.

The sooner cancer is treated, the greater the chances of a cure. This is why it is important to know the warning signs of cancer. Having warning signs does not mean that you have cancer. However, you should see a doctor to be sure. Everyone should know the warning signs of cancer. Detecting and treating cancer early can often lead to a cure. Some warning signs of cancer include:

- Change in bowel or bladder habits.
- Sores that do not heal.
- Unusual bleeding or discharge.
- Lump in the breast or elsewhere.
- Chronic indigestion.
- Difficulty swallowing.
- Obvious changes in a wart or mole.
- Persistent cough or hoarseness.

Diabetes

Another noninfectious disease is diabetes. **Diabetes** happens when the pancreas cannot make enough insulin. Insulin is a hormone that helps cells take up sugar from the blood. Without enough insulin, the blood contains too much sugar. This can damage blood vessels and other cells throughout the body. The kidneys work hard to filter out and remove some of the extra sugar. This leads to frequent urination and excessive thirst.

There are two main types of diabetes, type 1 diabetes and type 2 diabetes. Type 1 diabetes makes up about 5 to 10 percent of all cases of diabetes in the United States. Type 2 diabetes accounts for most of the other cases. Both types of diabetes are more likely in people that have certain genes. Having a family member with diabetes increases the risk of developing the disease.

Either type of diabetes can increase the chances of having other health problems. For example, people with diabetes are more likely to develop heart disease and kidney disease. Type 1 and type 2 diabetes are similar in these ways. However, the two types of diabetes have different causes.

Type 1 Diabetes

Type 1 diabetes happens when the immune system attacks normal cells of the pancreas. Since the cells in the pancreas are damaged, the pancreas cannot make insulin. Something in the environment causes the immune system to attack the pancreas, but it is unknown. Scientists think that the cause may be a virus. Type 1 diabetes usually develops in childhood or adolescence.

People with type 1 diabetes must frequently check the sugar in their blood. They use a meter like the one shown in **Figure** 10.12. Whenever their blood sugar starts to get too high, they need a shot of insulin. The insulin brings their blood sugar back to normal. There is no cure for type 1 diabetes. Therefore, insulin shots must be taken for life. Most people with this type of diabetes learn how to give themselves insulin shots.

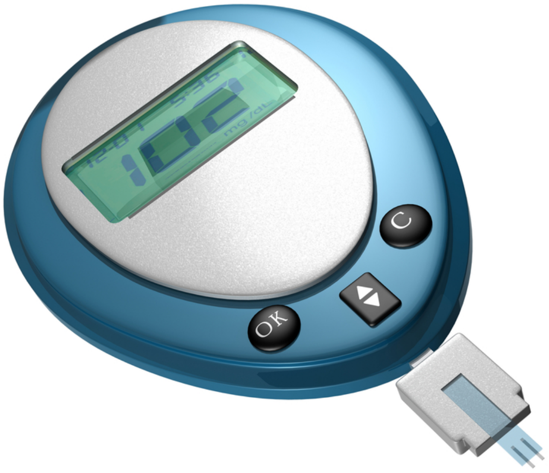


Figure 10.12: This is one type of meter used by people with diabetes to measure their blood sugar. Modern meters like this one need only a drop of blood and take less than a minute to use.

Type 2 Diabetes

Type 2 diabetes happens when body cells can no longer use insulin. The pancreas may still make insulin, but the cells of the body cannot use it. Being overweight and having high blood pressure increase the chances of developing type 2 diabetes. Type 2 diabetes usually develops in adulthood, but it is becoming more common in teens and children. This is because more young people are overweight now than ever before.

Some cases of type 2 diabetes can be cured with weight loss. However, most people with the disease need to take medicine to control their blood sugar. Regular exercise and balanced eating also help. Like people with type 1 diabetes, people with type 2 diabetes must frequently check their blood sugar.

Diseases of the Immune System

The immune system usually protects you from pathogens and other causes of disease. Later in this chapter, you will read more about how the immune system works. When the immune system is working properly, it keeps you from getting sick. But the immune system is like any other system of the body. It can break down or develop diseases.

In the last lesson you read about AIDS. AIDS is an infectious disease of the immune system caused by a virus. Some diseases of the immune system are noninfectious. They include autoimmune diseases and allergies.

Autoimmune Diseases

Does it make sense for an immune system to attack the cells it is meant to protect? No, but an immune system that does not function properly will attack its own cells. An **autoimmune disease** is a disease in which the immune system attacks the body's own cells.

One example is type 1 diabetes. In this disease, the immune system attacks cells of the pancreas. Other examples are multiple sclerosis and rheumatoid arthritis. In multiple sclerosis, the immune system attacks nerve cells. This causes weakness and pain. In rheumatoid arthritis, the immune system attacks the cells of joints. This causes joint damage and pain. These diseases cannot be cured. But they can be helped with medicines that weaken the immune system's attack on normal cells.

Allergies

An **allergy** is when the immune system attacks a harmless substance that enters the body from the outside. A substance that causes an allergy is called an allergen. It is the immune system, not the allergen, that causes the symptoms of an allergy.

Did you ever hear of hay fever? It's not really a fever at all. It's an allergy to plant pollens. People with this type of allergy have symptoms such as watery eyes, sneezing, and a runny nose. A common cause of hay fever is the pollen of ragweed. A ragweed plant is shown in **Figure** 10.13.

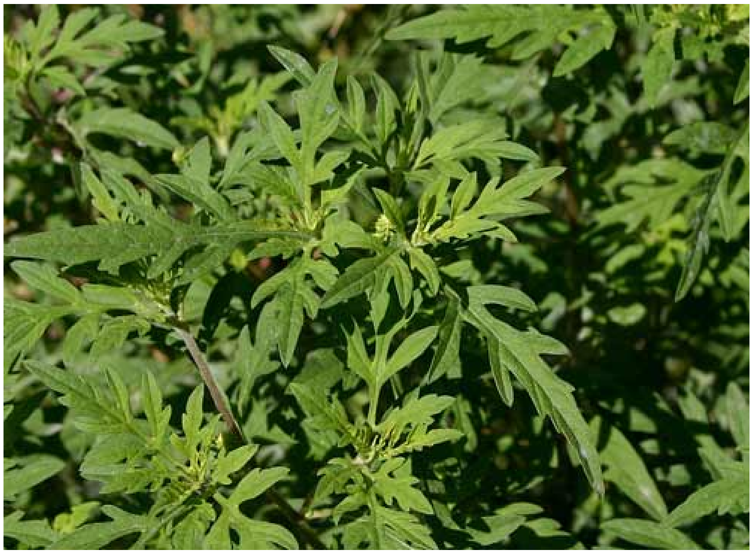


Figure 10.13: Ragweed is a common roadside weed found throughout the United States. Many people are allergic to its pollen.

Many people are allergic to poison ivy. A poison ivy plant is shown in **Figure** 10.14. Skin contact with poison ivy leads to an itchy rash in people that are allergic to the plant.

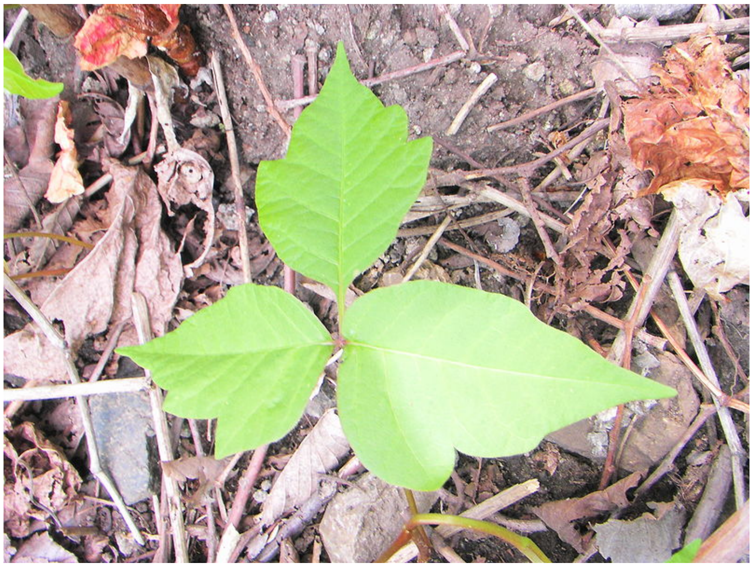


Figure 10.14: Poison ivy plants are wild vines with leaves in groups of three. They grow in wooded areas in most of the United States. Contact with poison ivy may cause a rash in a person allergic to the plant.

As you have read, some people are allergic to certain foods. Nuts and shellfish are common causes of food allergies. Other common causes of allergies include:

- Drugs such as penicillin.
- Mold.
- Dust.
- The dead skin cells, called dander, of dogs and cats.
- Stings of wasps and bees.

To learn more about allergies and their causes, go to `http://topics.healthvideo.com/m/21404533/seasonal-and-chronic-allergies.htm#q=OR+Allergy+OR+Allergies`. You can watch a video about allergies at this Web site.

Most allergies can be treated with medicines. Medicines used to treat allergies include antihistamines and corticosteroids. These medicines help control the immune system when it attacks an allergen.

Sometimes, allergies cause severe symptoms. For example, they may cause the throat to swell so it is hard to breathe. Severe allergies may be life threatening. They require emergency medical care.

Preventing Noninfectious Diseases

Most allergies can be prevented by avoiding the substances that cause them. For example, you can avoid pollens by staying indoors as much as possible. You can learn to recognize plants like poison ivy and not touch them. A good way to remember how to avoid poison ivy is ”leaves of three, let it be.”

Some people receive allergy shots to help prevent allergic reactions. The shots contain tiny amounts of allergens. After many months or years of shots, the immune system gets used to the allergens and no longer responds to them.

Type 1 diabetes and other autoimmune diseases cannot be prevented. But choosing a healthy lifestyle can help prevent type 2 diabetes. Getting plenty of exercise, avoiding high-fat foods, and staying at a healthy weight can reduce the risk of developing this type of diabetes. This is especially important for people that have family members with the disease.

Making these healthy lifestyle choices can also help prevent some types of cancer. In addition, you can lower the risk of cancer by avoiding carcinogens. For example, you can reduce your risk of lung cancer by not smoking. You can reduce your risk of skin cancer by using sunscreen. How to choose a sunscreen that offers the most protection is explained in **Figure** 10.15. Some people think that tanning beds are a safe way to get a tan. This is a myth. Tanning beds expose the skin to UV radiation. Any exposure to UV radiation increases in the risk of skin cancer. It doesn't matter whether the radiation comes from tanning lamps or the sun.

Figure 10.15: When you choose a sunscreen, select one with an SPF of 30 or higher. Also, choose a sunscreen that protects against both UVB and UVA radiation.

Lesson Summary

- Causes of noninfectious diseases may include genes and an unhealthy lifestyle.
- Cancer is caused by mutations and treated with surgery, drugs, and radiation.
- Diabetes is a disease that happens when the pancreas cannot make enough insulin or use the insulin properly.
- Autoimmune diseases occur when the immune system attacks normal body cells.
- Allergies occur when the immune system attacks harmless substances that enter the body from the outside.

- A healthy lifestyle can help reduce your risk of developing many noninfectious diseases.

Review Questions

Recall

1. What is a noninfectious disease?
2. List three carcinogens.
3. What other health problems are more likely in people with diabetes?
4. What causes rheumatoid arthritis?
5. How can you reduce your risk of developing skin cancer?

Apply Concepts

6. Explain how mutations can lead to cancer.
7. Why are frequent urination and excessive thirst symptoms of diabetes?
8. Compare and contrast type 1 and type 2 diabetes.

Critical Thinking

9. Some allergies affect people during certain seasons, while affect people year-round. Give examples of allergens that you would expect to cause each type of allergy.

10. Why is maintaining a healthy weight especially important for people that have family members with type 2 diabetes?

Further Reading / Supplemental Links

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- Jillian Powell. *Allergies.* Cherrytree Books, 2008.
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- http://www.cancerindex.org/ccw/guide2c.htm http://www.cancer.gov/cancertopics/understandingca immunesystem; http://www.cancerindex.org/ccw/guide2c.htm
- http://www.mayoclinic.com/health/allergy/AA99999 http://www.cdc.gov/cancer/az/; http://www.mayoclinic.com/health/allergy/AA99999
- http://www.4women.gov/FAQ/autoimmune.htm http://www.uihealthcare.com/topics/cancer/canc4280.html; http://www.4women.gov/FAQ/autoimmune.htm
- http://en.wikipedia.org/wiki

Points to Consider

- How do you think the body fights diseases like colds?
- How do you think the immune system protects you from pathogens and other causes of disease?

10.3 First Two Lines of Defense

Lesson Objectives

- Describe your body's first line of defense against pathogens.
- Explain how inflammation helps protect you from pathogens.

Check Your Understanding

- What are some of the functions of your skin?
- What is a pathogen? Give some examples.

Vocabulary

fever inflammation mucus
phagocytes phagocytosis

First Line of Defense

Your body has many ways to protect you from pathogens. Your body's defenses are like a castle of old. The outside of a castle was protected by a moat and high walls. Inside the castle, soldiers were ready to fight off any enemies that made it across the moat and over the walls. Like a castle, your body has a series of defenses. Only pathogens that get through all the defenses can harm you.

Your body's first line of defense is like a castle's moat and walls. It keeps most pathogens out of your body. The first line of defense includes different types of barriers.

Skin and Mucous Membranes

The skin is a very important barrier to pathogens. The skin is the body's largest organ. In adults, it covers an area of about 16 to 22 square feet!

The skin is also the body's most important defense against disease. It forms a physical barrier between the body and the outside world. As shown in **Figure** 10.16, the skin has several layers. The outer layer is tough and waterproof. It is very difficult for pathogens to get through this layer of skin.

The mouth and nose are not lined with skin. Instead, they are lined with mucous membranes. Other organs that are exposed to the outside world, including the lungs and stomach, are also lined with mucous membranes. Mucous membranes are not tough like skin, but they have other defenses.

One defense of mucous membranes is the mucus they release. **Mucus** is a sticky, moist substance that covers mucous membranes. Most pathogens get stuck in the mucus before they can do harm to the body. Many mucous membranes also have cilia. Cilia in the lungs are shown in **Figure** 10.17. Cilia are like tiny finger-like projections. They move in waves and sweep mucus and trapped pathogens toward body openings. When you clear your throat or blow your nose, you remove mucus and pathogens from your body.

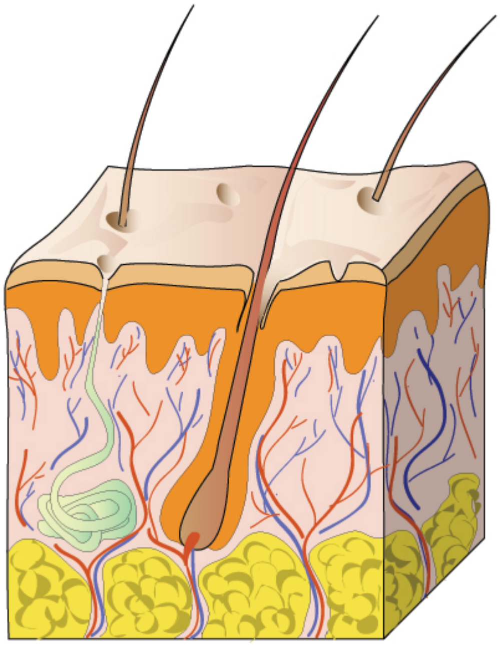

Figure 10.16: This drawing shows that the skin has many layers. The outer layer is so tough that it keeps out most pathogens.

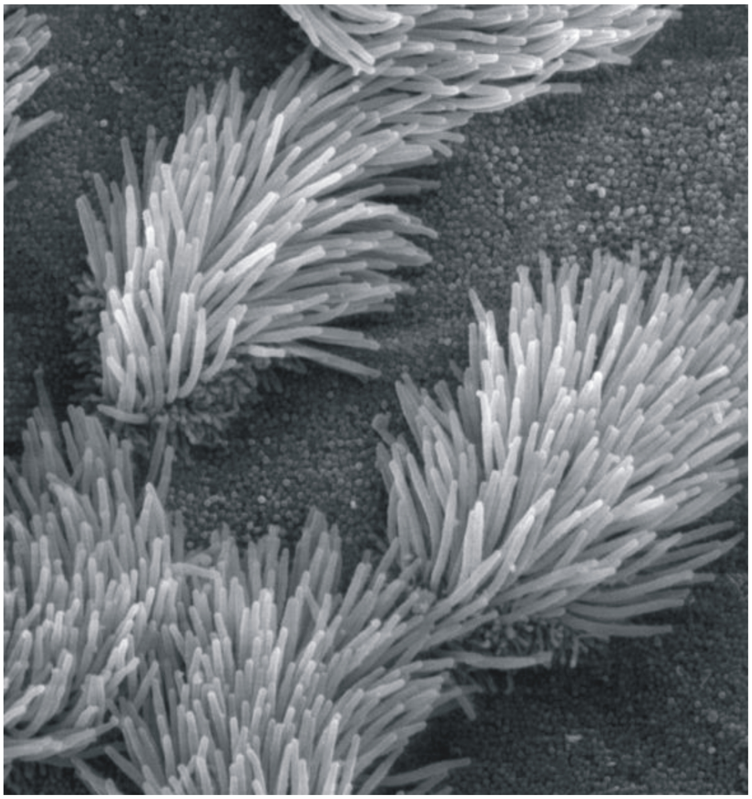

Figure 10.17: This is what the cilia lining the lungs look like when they are magnified. Their movements constantly sweep mucus and pathogens out of the lungs. Do they remind you of brushes?

Chemicals

Most body fluids that you release from your body contain chemicals that kill pathogens. For example, mucus, sweat, tears, and saliva contain enzymes that kill pathogens. The enzymes are called lysozymes. They break down the cell walls of bacteria to kill them.

The stomach also releases a very strong acid, called hydrochloric acid. This acid kills most pathogens that enter the stomach in food or water. Urine is also acidic, so few pathogens can grow in it.

Helpful Bacteria

You are not aware of them, but your skin is covered by millions (or more!) of bacteria. Millions more live inside your body. From the *Food and Digestive System* chapter, you know that many bacteria live inside your large intestine. Most of these bacteria help defend your body from pathogens. How do they do it? They compete with harmful bacteria for food and space. This prevents the harmful bacteria from multiplying and making you sick.

Second Line of Defense

The little girl in **Figure** 10.18 has a scraped knee. A scrape is a break in the skin that may let pathogens enter the body. If bacteria enter through the scrape, they could cause an infection. These bacteria would then face the body's second line of defense.

Inflammation

If bacteria enter the skin through a scrape, the area may become red, warm, and painful. These are signs of inflammation. **Inflammation** is one way the body reacts to infections or injuries. Inflammation is caused by chemicals that are released when skin or other tissues are damaged. The chemicals cause nearby blood vessels to dilate, or expand. This increases blood flow to the damaged area. The chemicals also attract white blood cells to the wound and cause them to leak out of blood vessels into the damaged tissue. You can watch a video animation of this process at `http://biology-animations.blogspot.com/search/label/inflammation`.

White Blood Cells

After white blood cells leave a blood vessel at the site of inflammation, they start "eating" pathogens. From the *Cardiovascular System* chapter, you know that white blood cells are one type of cell that makes up the blood.

The main role of white blood cells is to fight pathogens in the body. There are actually several different kinds of white blood cells. Some white blood cells have very specific functions. They attack only certain pathogens. You will read about these white blood cells later in this chapter.

Other white blood cells attack any pathogens they find. These white blood cells travel to areas of the body that are inflamed. They are called **phagocytes**, which means "eating cells." In addition to pathogens, phagocytes "eat" dead cells. They surround the pathogens and destroy them. This process is called **phagocytosis**. How phagocytosis occurs is shown in **Figure** 10.19. You can watch a video of a phagocyte gobbling up and destroying a pathogen at `http://sciencevideos.wordpress.com/2007/09/26/defense-against-infectious-disease/`.

Figure 10.18: This little girl just got her first scraped knee. It doesn't seem to hurt, but the break in her skin could let pathogens enter her body. That's why scrapes should be kept clean and protected until they heal.

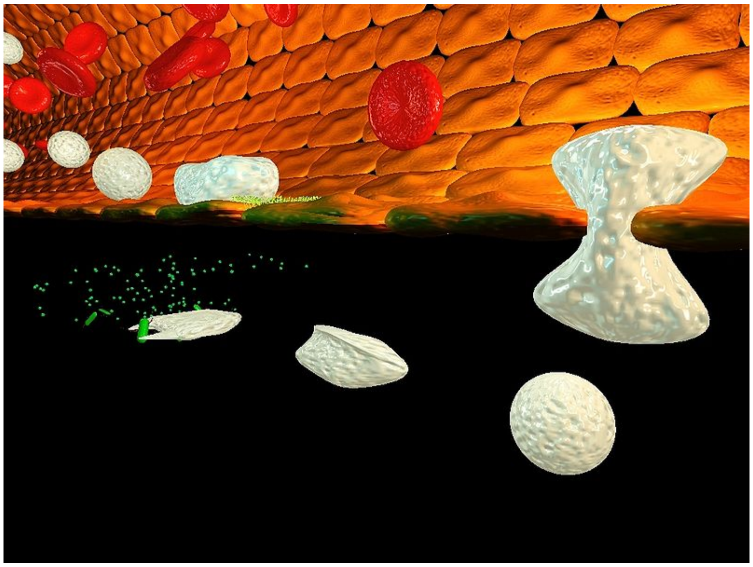

Figure 10.19: This drawing show phagocytosis. In this process, a phagocyte surrounds a pathogen and breaks it down as shown by the white blood cell attacking the green bacteria.

White blood cells also make chemicals that cause a fever. A **fever** is a higher-than-normal body temperature. Normal human body temperature is 98.6° F (37° C). Most bacteria and viruses that infect people reproduce fastest at this temperature.

When the temperature is higher, the pathogens cannot reproduce as fast, so the body raises the temperature to kill them. A fever also causes the immune system to make more white blood cells. In these ways, a fever helps the body fight infection.

Lesson Summary

- Your body's first line of defense includes the skin and other barriers that keep pathogens out of your body.
- If pathogens enter your body, inflammation occurs, and phagocytes come to the body's defense.

Review Questions

Recall

1. How does your skin protect you from pathogens?
2. What is mucus?
3. Define inflammation.
4. What are phagocytes?
5. What is a fever?

Apply Concepts

6. Explain how cilia help rid your body of pathogens.

7. How do helpful bacteria defend your body?
8. How does inflammation help fight pathogens?

Critical Thinking

9. Why is phagocytosis called a *general* body defense?
10. A fever is a sign of infection. Why might it be considered a good sign?

Further Reading / Supplemental Links

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- Susan Heinrichs Gray. *The Skin.* Child's World, 2005.
- `http://hypertextbook.com/facts/2001/IgorFridman.shtml`
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- `http://en.wikipedia.org/wiki`

Points to Consider

- How do you think pathogens can be recognized?
- Why do you think the body needs specific defenses as well as general ones?

10.4 Immune System Defenses

Lesson Objectives

- Describe the immune system.
- Explain how lymphocytes respond to pathogens.
- Define immunity and vaccination.

Check Your Understanding

- What are the first two lines of defense?
- Give examples of pathogens.

Vocabulary

antigen immune response immune system
immunity lymph lymph nodes
lymphocytes vaccination

What Is the Immune System?

If pathogens get through the body's first two lines of defense, a third line of defense takes over. This third line of defense involves the immune system. It is called an **immune response**. The immune system has a special response for each type of pathogen.

The **immune system** is also part of the lymphatic system - named for **lymphocytes**, which are the type of white blood cells involved in an immune response. You can see the parts of the immune system in **Figure** 10.20. They include several lymph organs, lymph vessels, lymph, and lymph nodes.

Lymph Organs

The lymph organs are the red bone marrow, thymus gland, spleen, and tonsils. Each organ has a different job in the immune system. They are described in **Figure** 10.21, **Figure** 10.22, **Figure** 10.23, and **Figure** 10.24.

Lymph and Lymph Vessels

Lymph vessels make up a circulatory system that is similar to the cardiovascular system, which you read about in the *Cardiovascular System* chapter. Lymph vessels are like blood vessels, except they move lymph instead of blood.

Lymph is a yellowish liquid that leaks out of tiny blood vessels into spaces between cells in tissues. Where there is more inflammation, there is usually more lymph in tissues. This lymph may contain many pathogens.

The lymph that collects in tissues slowly passes into tiny lymph vessels. It then travels from smaller to larger lymph vessels. Lymph is not pumped through lymph vessels like blood is pumped through blood vessels by the heart. Instead, muscles around the lymph vessels contract and squeeze the lymph through the vessels. The lymph vessels also contract to help move the lymph along. The lymph finally reaches the main lymph vessels in the chest. Here, the lymph drains into two large veins. This is how the lymph returns to the bloodstream.

Before lymph reaches the bloodstream, pathogens are removed from it at lymph nodes. **Lymph nodes** are small, oval structures located along the lymph vessels. They act like filters. Any pathogens filtered out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

Lymphocytes

Lymphocytes (white blood cells) are the key cells of an immune response. A photograph of a lymphocyte is shown in **Figure** 10.25. There are trillions of lymphocytes in the human body. They make up about one quarter of all white blood cells. Usually, fewer than half of the body's lymphocytes are in the blood. The rest are in the lymph, lymph nodes, and lymph organs.

There are two main types of lymphocytes:

1. B cells.
2. T cells.

Both types of lymphocytes are produced in the red bone marrow. They are named for the sites where they grow larger. The "B" in B cells stands for "bone." B cells grow larger in red bone marrow.

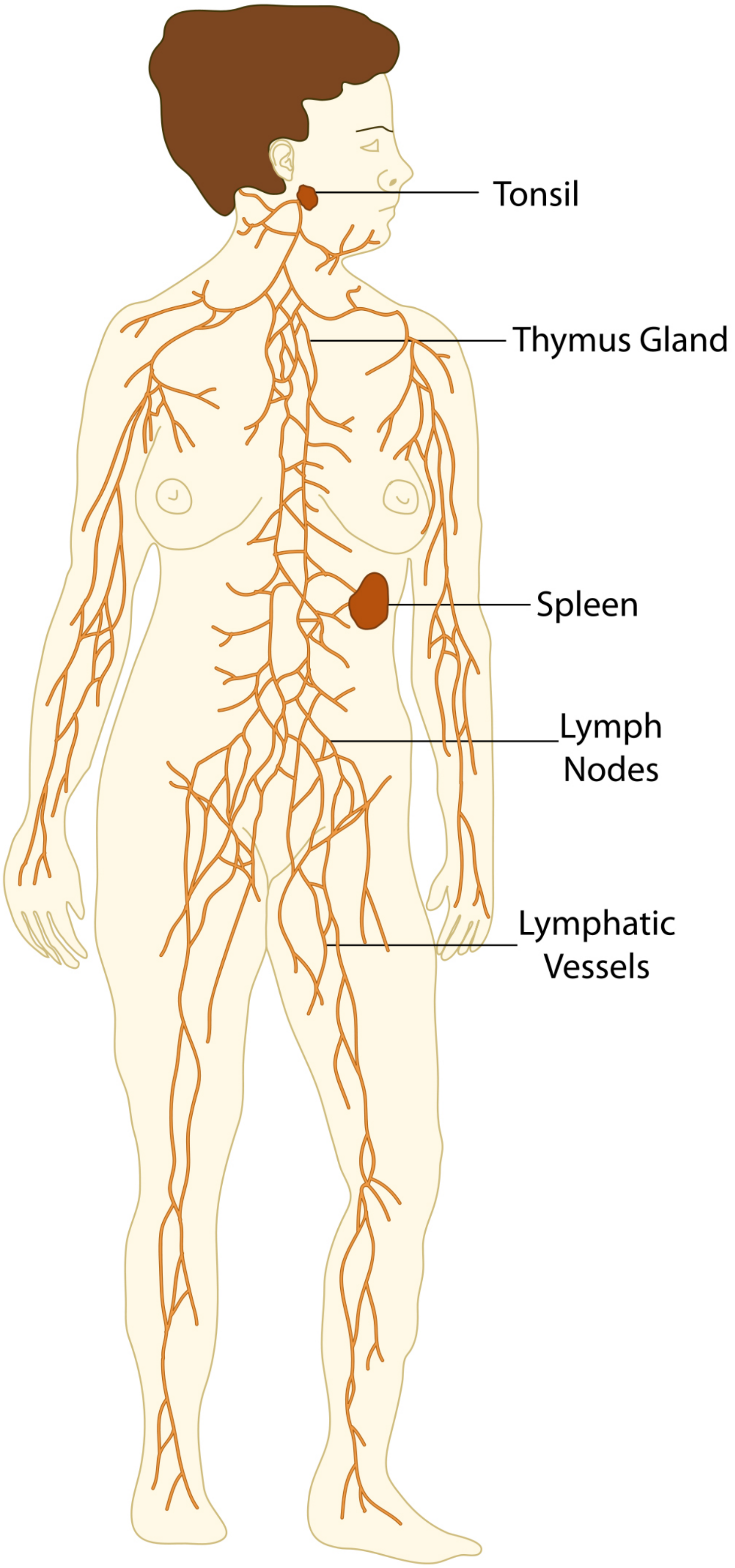

Figure 10.20: This diagram shows the parts of the immune system. The immune system includes several organs and a system of vessels that carry lymph. Lymph nodes are located along the lymph vessels.

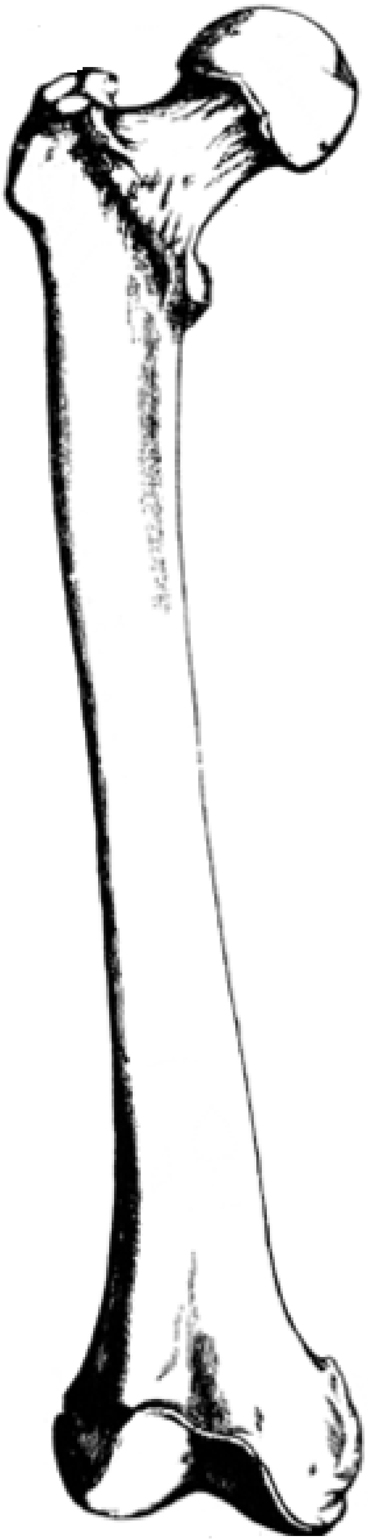

Figure 10.21: Red bone marrow is found inside many bones, including the femur shown here. Red bone marrow makes lymphocytes.

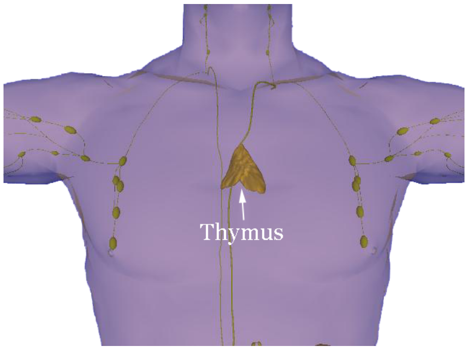

Figure 10.22: The thymus gland is in the chest behind the breast bone. It stores lymphocytes while they grow older.

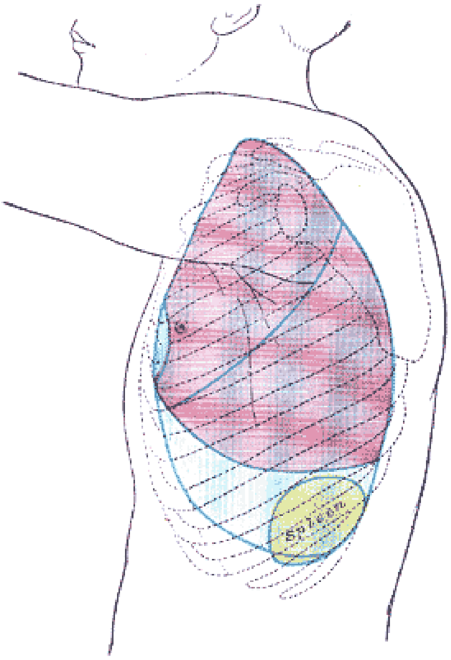

Figure 10.23: The spleen is in the abdomen below the lungs. Its job is to filter the toxins out of the blood. Any pathogens that are filtered out of the blood are destroyed by lymphocytes in the spleen.

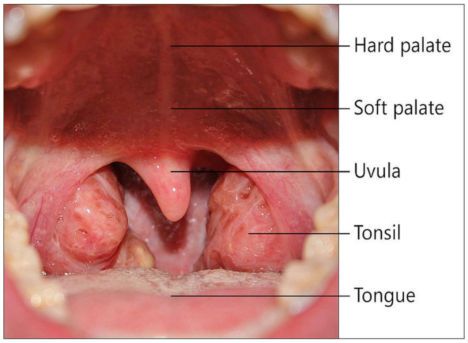

Figure 10.24: The tonsils are in the throat. They trap pathogens that enter the body through the mouth or nose. Lymphocytes in the tonsils destroy the trapped pathogens.

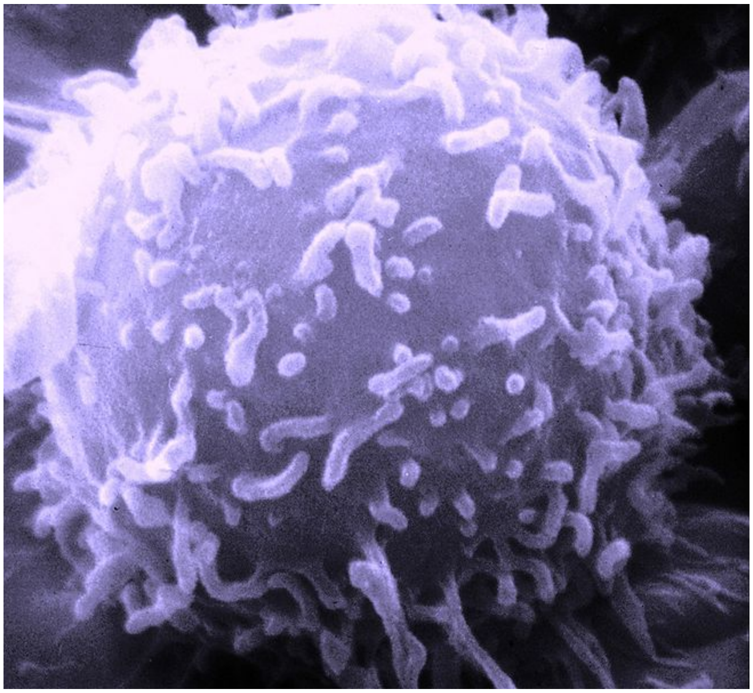

Figure 10.25: This image of a lymphocyte was made with an electron microscope. The lymphocyte is shown 10,000 times its actual size.

The ”T” in T cells stands for “thymus.” T cells mature in the thymus gland. B and T cells must be “switched on” in order to fight a specific pathogen. Once this happens, they produce an army of cells ready to fight that particular pathogen.

How can B and T cells recognize specific pathogens? Pathogens have proteins, often located on their cell surface. These proteins are called antigens. An **antigen** is any protein that causes an immune response, because it is unlike any protein that the body makes. Antigens are found on bacteria, viruses, and other pathogens. They are also found on other cells, like allergens, that enter the body and on cancer cells.

Immune Responses

There are two different types of immune responses. One type involves B cells. The other type involves T cells. You can watch a video of both types of immune responses at `http://www.dnatube.com/view_video2.php?viewkey=5ff68e3e25b9114205d4`.

B Cell Response

B cells respond to pathogens and other cells from outside the body in the blood and lymph.

Most B cells fight infections by making antibodies. An antibody is a large, Y-shaped protein that binds to an antigen. Each antibody can bind with just one specific type of antigen. They fit together like a lock and key. Once an antigen and antibody bind together, they signal for a phagocyte to destroy them. A diagram of an antibody binding with an antigen is shown in **Figure** 10.26.

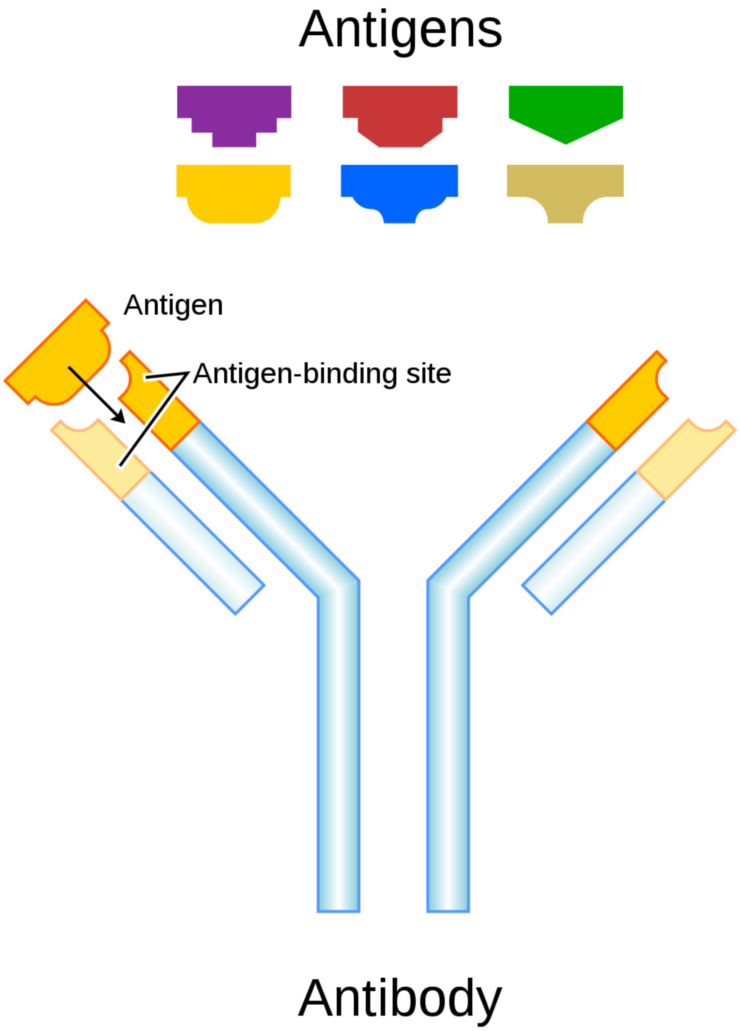

Figure 10.26: This diagram shows how an antibody binds with an antigen. The antibody was produced by a B cell. It binds with just one type of antigen. Antibodies produced by different B cells bind with other types of antigens.

T Cell Response

There are different types of T cells, including killer T cells and helper T cells. Killer T cells destroy infected, damaged, or cancerous body cells. How a killer T cell destroys an infected cell is shown in **Figure** 10.27. When the killer T cell comes into contact with the infected cell, it releases poisons. The poisons make tiny holes in the cell membrane of the infected cell. This causes the cell to burst open. Both the infected cell and the viruses inside it are destroyed.

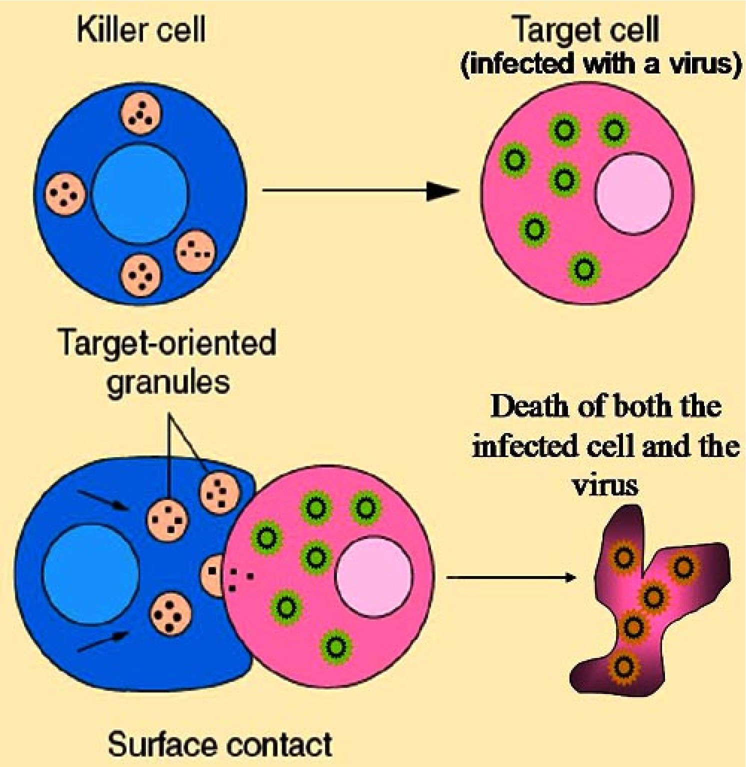

Figure 10.27: In this diagram, a killer T cell recognizes a body cell infected with a virus. After the killer T cell makes contact with the infected cell, it releases poisons that cause the infected cell to burst. This kills both the infected cell and the viruses inside it.

Helper T cells do not destroy infected or damaged body cells. But they are still necessary for an immune response. They help by releasing chemicals that control other lymphocytes. The chemicals released by helper T cells "switch on" both B cells and killer T cells so they can recognize and fight specific pathogens.

Immunity and Vaccination

Most B and T cells die after an infection has been brought under control. But some of them survive for many years. They may even survive for a person's lifetime.

These long-lasting B and T cells are called memory cells. They allow the immune system to "remember" the pathogen after the infection is over. If the pathogen invades the body again, the memory cells will start dividing in order to fight on the disease.

They will quickly produce a new army of B or T cells to fight the pathogen. They will begin a faster, stronger attack than the first time the pathogen invaded the body. As a result, the immune system will be able to destroy the pathogen before it can cause an infection. Being able to attack the pathogen in this way is called **immunity**.

Immunity can also be caused by vaccination. **Vaccination** is the process of exposing a person to a pathogen on purpose in order to develop immunity. In vaccination, the pathogen is usually injected under the skin by a shot. Only part of the pathogen is injected, or a weak or dead pathogen is used. It sounds dangerous, but the shot causes an immune response without causing the actual illness. Diseases you have probably been vaccinated against include measles, mumps, and chicken pox.

Lesson Summary

- The immune system includes lymph organs, lymph vessels, lymph, and lymph nodes.
- B cells produce antibodies against pathogens in the blood and lymph.
- Killer T cells destroy body cells infected with pathogens.
- Immunity is the ability to resist a particular pathogen.
- Vaccination is deliberate exposure to a pathogen in order to bring about immunity.

Review Questions

Recall

1. What are lymphocytes?

2. What is lymph?

3. What is an antigen?

4. What organ produces B cells and T cells?

5. Define immunity.

Apply Concepts

6. How are an antigen and antibody like a lock and key?

7. Explain how killer T cells fight pathogens.

8. Helper T cells do not produce antibodies or destroy infected cells. Why are they necessary for immune responses?

9. If you have been vaccinated against measles, you are unlikely to ever have the disease, even if you are exposed to the measles virus. Why?

Critical Thinking

10. Some children with frequent sore throats have an operation to remove their tonsils. Why might removing the tonsils lead to fewer sore throats?

Further Reading / Supplemental Links

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- Steve Parker. *Defend Yourself: The Immune System.* Raintree, 2006.

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- http://en.wikipedia.org/wiki

Points to Consider

- What do you think is the role of the reproductive system?
- Do you know what organs and other structures make up the reproductive system?
- Do you know how they differ between males and females?

Image Sources

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